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LDCM

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LDCM Project

Mission Operations Element Requirements Document

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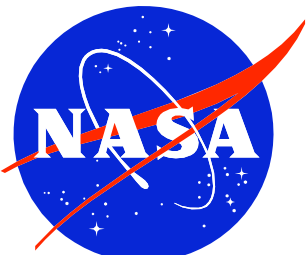
Signature Page

Prepared by: Robert Shendock LDCM Ground Systems Engineer SGT, Contractor to NASA GSFC	Date	Prepared by: Jason Williams LDCM Flight Operations Segment System Engineer SAIC, Contractor to the USGS EROS	Date
Reviewed by: Vicki Zanoni LDCM Ground System Manager NASA GSFC Code 581	Date	Reviewed by: Steve Walters LDCM Flight Operations Segment Manager USGS EROS	Date
Reviewed by: Steve Coyle LDCM Mission Operations Manager NASA GSFC Code 581	Date	Reviewed by: Ronald Smilek LDCM Mission Operations Manager USGS	Date
Reviewed by: Evan Webb LDCM Mission Systems Engineer NASA GSFC Code 599	Date	Reviewed by: Bill Anselm LDCM Observatory Manager NASA GSFC Code 427	Date
Reviewed by: Del Jenstrom LDCM Deputy Project Manager NASA GSFC Code 427	Date	Reviewed by: Tom Kalvelage LDCM Chief Engineer USGS	Date
Approved by: William Ochs LDCM Project Manager NASA GSFC Code 427	Date	Approved by: Mike Headley LDCM Project Manager USGS	Date

Document Revision History

This document is controlled by the LDCM Project Management. Changes require prior approval of the LDCM Project Manager, LDCM observatory Manager, and the LDCM Mission Assurance Manager. Proposed changes shall be submitted to LDCM Mission Systems Engineer.

RELEASE	DATE	BY	DESCRIPTION
–			Initial Version

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1 Introduction

1.1 Scope

The Mission Operations Element Requirements Document (MOERD) establishes the procurement requirements for the LDCM Mission Operations Element. It is a Level 3 document that contains the functional and performance requirements for the software and hardware systems comprising the Mission Operations Element.

Detailed requirements, design, implementation, and operation are not defined in this document. It is expected that the MOE will include all detailed functions needed to successfully operating the LDCM observatory for the life of the mission.

The grouping of functions within the sections of this document is strictly for organizational purposes. Grouping or categorizing requirements is not in any way intended to imply MOE system or sub-system architecture or design.

1.2 Mission Operations Element (MOE) Overview

The LDCM Mission Operations Element (MOE) is that part of the LDCM Flight Operations Segment that provides the primary means to communicate with the observatory and conduct the LDCM mission as described in the LDCM Operations Concept (Ref Doc. 427-02-02).

The MOE software and hardware systems will reside at the LDCM Mission Operations Center (MOC), a government facility located at the USGS Center for Earth Resources Observation and Science (EROS)..   For operations contingency purposes a backup MOE (bMOE) will reside at a backup MOC (bMOC) facility, located at a geographically separate location from the MOC. The primary MOE and the bMOE interface for data transfer and operational transfer of observatory command and control.

The MOE consists of six primary functions:

- Command and Control

- Planning and Scheduling

- Trending & Analysis

- Flight Dynamics

- Memory Management

- Automation of Operations

The MOE functions are not intended to imply a particular MOE architecture or system design.

The Command and Control function generates, verifies, and sends observatory command loads for transmission to the observatory. Command loads are built to implement observatory activity schedules and flight software updates. The Command and Control function monitors the LDCM observatory through the receipt, processing, and monitoring of observatory telemetry.

The Planning and Scheduling function builds and manages an activity schedule for the LDCM observatory. The schedule incorporates requests for image collections that are generated by the Collection Activity Planning Element (CAPE) of the LDCM Flight Operations Segment. Refer to section 1.3 for further details. The MOE schedules the CAPE requested scenes, organizes them into intervals, and returns interval identifier to scene identifier mappings to the CAPE. The MOE performs planning and scheduling of the CAPE-requested and other observatory activities such as orbit adjustments, maneuvers, ground station contacts, instrument calibration requests and other events that occur on board the observatory.

The Trending & Analysis functions process near- and long-term observatory telemetry data. This function is used to trend and analyze the performance of the observatory for state of health monitoring using all collected housekeeping data (e.g., potential problems with the observatory attitude, power, temperature, or other subsystems).

The Flight Dynamics functions provide attitude estimation and sensor calibration, orbit prediction, maneuver planning, definitive ephemeris generation, mission planning products and ground station acquisition data.

Management of observatory memory falls into three categories. In order of increasing frequency of use, they are: observatory flight software, flight operations-owned data elements and solid state recorder management. Updates to the LDCM observatory flight software will be provided to the MOE by the LDCM Mission Contractor. The MOE will build and send the command loads to update the flight software on the observatory. Periodic table and stored command sequence maintenance may be performed by the Flight Operations Team (FOT). The MOE will provide the capabilities necessary to build the command loads and verify their uplink. Current copies of the on-board memory images will be maintained by the MOE. On-board data storage and recovery is performed on a routine basis. The MOE will support these operations in manual and autonomous modes of operation.

Ground operations utilizing the MOE will be sufficiently automated to support 8X5 operations with continuous periods of un-attended operations in excess of 72-hours.

1.3 Overview of the Flight Operations Segment (FOS)

This section is not intended to describe the MOE functionality. It illustrates the MOE role in the overall collection planning process and elaborates on the related interfaces.
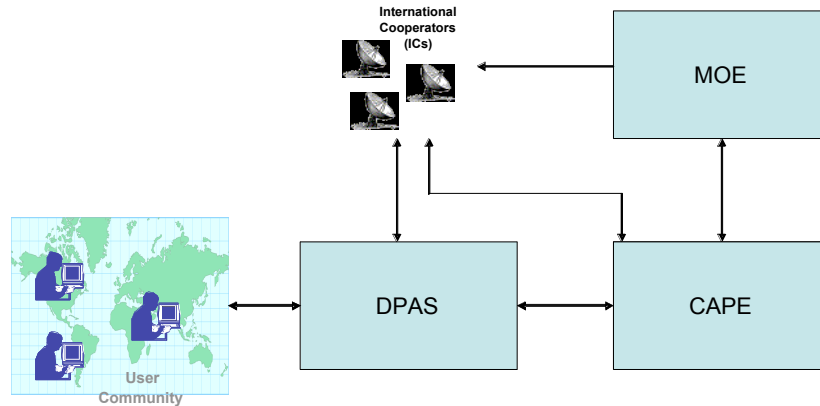
Figure 1-1 – LDCM data collection planning context

The Collection Activity Planning Element (CAPE) is the LDCM component which determines the data (at a scene level) that will be acquired by the observatory's imaging sensor(s). The scenes to be collected are largely determined by a set of algorithms running with a set of global imaging requirements expressed as the Global Mission Acquisition Plan (LTAP). In addition to these, individual requests from agencies and users in the LDCM User Community are submitted through the Data Processing and Archiving Segment (DPAS). The DPAS forwards all requests to the CAPE for consideration. The CAPE also receives observatory and resource unavailability times from the MOE as in input to image data planning.

International Cooperators (ICs) typically submits requests for image data to the CAPE using a mask or table that provides the relative priority of scenes in their region. ICs may also submit requests for specific acquisitions through the same DPAS functionality as the rest of the User Community. ICs notify the CAPE of any ground station outages or desired changes in data collection.

The CAPE processes all these inputs (and others) to produce a final Collection Activity Request, which is a scene-based list of image data to be acquired by the observatory. This scene based list corresponds to nominal WRS-2 path/row footprints on the ground. The MOE ingests this list and uses it to generate the detailed spacecraft activity schedules, including determining imaging intervals. After doing the detailed observatory schedule the MOE informs the CAPE of the status of all the scenes in the Collection Activity Request. The MOE also factors in observatory health & safety operations, orbital maneuvers and other operations which the CAPE is not involved in scheduling.

2 Applicable and Reference Documents

2.1 Applicable Documents

The MOERD is consistent with and responsive to the following applicable documents.

Document Number	Revision/ Release Date	Document Title
427-06-03	Draft March 23, 2007	LDCM Observatory Requirements Document
427-06-01	Draft February, 2007	LDCM Launch System Requirements Document
GSFC STD-1000	Rev C.2 December 12, 2006	Rules for the Design, Development, Verification and Operation of Flight Systems
NPD 8010.2E	March 04, 2007	NASA Policy Directive, Use of the SI (Metric) System of Measurement in NASA Programs
NPR 2810.1A	May 16, 2006	NASA Procedural Requirement, Security of Information Technology
450-SNUG	June 2002	Space Network (SN) Users' Guide, Revision 8
453-GNUG	February 2005	Ground Network (GN) User's Guide, Revision 1
452-ICD-SN/CSM	May 2004	Interface Control Document Between the Space Network and Customers for Service Management
CCSDS 231.0–B–1	September 2003	Recommendation for Space Data Systems Standards. TC Synchronization and Channel Coding. Blue Book. Issue 1.
CCSDS 231.0–B–1 Cor.1	June 2006	Recommended Standard Technical Corrigendum 1 to CCSDS 231.0-B-1, Issued September 2003. Blue Book. Issue 1.
CCSDS 232.0–B–1	September 2003	Recommendation for Space Data Systems TC Space Data Link Protocol. Blue Book. Issue 1.

Document Number	Revision/ Release Date	Document Title
CCSDS 232.1–B–1	September 2003	Recommendation for Space Data Systems Standards. Communications Operations Procedure-1. Blue Book. Issue 1.
CCSDS 133.0-B-1	September 2003	Recommendation for Space Data Systems Standards TM Space Packet Protocol. Blue Book. Issue 1.
CCSDS 131.0-B-1	September 2003	Recommendation for Space Data Systems Standards TM Synchronization and Channel Coding
CCSDS 727.0-B-4	January 2007	Recommendation for Space Data Systems Standards CCSDS File Delivery Protocol (CFDP)
CCSDS 732.0-B-1	July 2006	Recommendation for Space Data Systems Standards AOS Space Data Link Protocol
CCSDS 910.4-B-2	October 2005	Cross Support Reference Model – Part 1: Space Link Extension Services. Blue Book. Issue 2.
CCSDS 911.1-B-2	November 2004	Space Link Extension – Return All Frames Service Specification. Blue Book. Issue 2.
CCSDS 911.2-B-1	November 2004	Space Link Extension – Return Channel Frames Service Specification. Blue Book. Issue 1.
CCSDS 911.5-B-1	November 2004	Space Link Extension – Return Operational Control Fields Service Specification. Blue Book. Issue 1.
CCSDS 912.1-B-2	November 2004	Space Link Extension – Forward CLTU Service Specification. Blue Book. Issue 2.
CCSDS 912.3-B-1	November 2004	Space Link Extension – Forward Space Packet Service Specification. Blue Book. Issue 1.

2.2 Reference Documents

The following documents provide further context for the MOERD and the LDCM.

Document Number	Revision/ Release Date	Document Title
427-02-06		LDCM Acronym List and Lexicon
427-02-02	Draft January 2007	LDCM Operations Concept Document
DCN	Draft April 2007	LDCM Mission Operations Center (MOC) Operations Concept
LDCM-OCD-001	Draft September, 2006	LDCM Collection Activity Planning Element (CAPE) Operations Concept Document (OCD)
427-09-xx	Draft April 2007	MOE Statement of Work
NASA-STD-8739.8	Baseline July 07, 2004	Software Assurance Standard
427-05-04		OLI Special Calibration Test Requirements (SCTR)
427-02-07	Rev -, January 4, 2007	Landsat World Reference System -2 (WRS-2) Definition
NPR 7150.2		NASA Software Engineering Requirements

3 Command and Control

This section defines the MOE requirements for command and telemetry processing.

The MOE shall be capable of concurrent commanding, real-time housekeeping telemetry receipt/ingest, stored housekeeping telemetry receipt/ingest, and telemetry playback.

Rationale: allows MOE to perform telemetry ingest and commanding at the same time

Each MOE workstation shall be individually configurable to define its command and telemetry processing attributes, including data stream access.

Rationale: allow the user to select command destination and data source selection. This allows users to connect to the simulator or view playback telemetry while other users are actively supporting a contact.

Each MOE workstation shall have the capability to display its user configurable command and telemetry processing attributes.

Rationale: allow the user to select command destination and data source selection. This allows users to connect to the simulator or view playback telemetry while other users are actively supporting a contact.

3.1 Link Management

The MOE shall establish, manage and terminate the forward and return links with the GNE, NGN and SN networks.

Rationale: The MOE front end shall be configurable to support forward and return link services with the networks via GSE directives.

The MOE shall provide the capability to assess and report the configuration and status of the forward and return links with any ground station.

Rationale: Data related to the status of the links is needed to support verification of directive activities and link status. Data sources may include GNE ground station status messages.

The MOE shall have the ability to configure the forward, return and status data streams between any ground station automatically based on the schedule or manually from the command console via directive.

Rationale: ability to establish links for commanding and telemetry; ensure only one station sends command to the observatory at a time

The time to configure forward, return, and status data streams between ground stations shall not exceed 5 seconds.

Rationale: quick configuration to set up link to observatory

The MOE shall make available for MOE use, the network (GNE, NGN, or SN) resource routing codes for which it is configured to support. This code will be available for use by Flight Operations Segment elements.

The MOE shall provide the capability to generate LDCM Ground Network (GNE) forward and return link service requests.

3.2 Commanding

This section defines the MOE requirements for commanding to manage the forward link to the observatory, issue commands generated within the MOC, perform hazardous/critical command checking, and perform command verification.

The MOE shall communicate with the observatory in accordance with the following Consultative Committee for Space Data Systems (CCSDS) Recommendations for Space Data Systems Standards:
  231.0-B-1 Telecommand Synchronization and Channel Coding,
  232.0-B-1 Telecommand Space Data Link Protocol,
  232.1-B-1 Communications Operations Procedure-1, and
  133.0-B-1 TM Space Packet Protocol
  727.0-B-4 File Delivery Protocol (CFDP).

The MOE shall be capable of generating commands to perform the observatory functions and requirements as defined in the LDCM Command Handbook and additional documents defining command definition and processing requirements.

The MOE shall be capable of generating commands to support CFDP Class II operations.

3.2.1 Command Encryption and Authentication

The LDCM command link will be encrypted using Caribou with Manual Bypass capability.

The MOE shall encrypt with the observatory in accordance with the following NSA Standards for NSA Command & Control authentication: CNSS Policy No. 12 National Information Assurance Policy for Space Systems Used to Support National Security Missions

The LDCM command shall be encrypted using Caribou implemented in a physical instantiation.

The LDCM command shall be implemented with Manual Bypass (clear mode) capability.

The MOE shall have the capability to perform commercially available command encryption compliant with NPR 2810.1A.

Rationale: project requirement based on the type of mission and threat assessment; provide protection against unauthorized attempt to command observatory

The MOE shall provide the capability to enable and disable the command encryption function.

Rationale: ability to turn off/on encryption if needed

The MOE shall provide the capability to authenticate all commands as originating from the LDCM MOE.

Rationale: additional level of security to ensure that commands are from the authorized source

The MOE shall provide the capability to enable and disable the command authentication capability.

Rationale: authentication may need to be disabled during emergency or contingency operations

3.2.2 Authorization for Commanding

The MOE shall provide the capability to assign levels of command authority to ensure that only authorized personnel can perform designated command functions.

Command authority shall be controlled by login attributes.

Rational: provides ability to assign different command privileges to different personnel.

The MOE shall provide the capability to allow authorized operators to transmit commands to the observatory.

Rationale: The MOE shall provide the capability to deny unauthorized operators access to system capabilities.

The MOE shall provide a mechanism to enable and disable access to the command link by operators other than the master.

Rationale: A central authority will have real-time control over user access to the command link.

The MOE shall prevent concurrent sending of commands by multiple operators.

Rationale: only one operator or terminal can send commands to the observatory at a time, supports command verification requirements.

3.2.3 Commanding Requirements

Requirements providing the capability to construct real-time commands and uplink loads for the observatory processor(s) are delineated in the following subsections.

The MOE shall provide the capability to perform real time commanding to the observatory.

Rationale: allows operator to generate and send command loads/sequences during a contact, manually from a command line input and/or as automated execution of pre-staged commands

The MOE shall provide the mechanisms to construct any real-time commands from operator provided bit pattern specified in hexadecimal.

Rationale: Provides the capability to construct commands not defined in the project database.

The MOE shall perform verification of real-time commands to the observatory.

The MOE shall provide notification to the operator of any invalid commands.

The MOE invalid command notifications shall include the specific reason for command transmission failure.

Rationale: operator feedback as to the nature of the command invalidity (e.g. "cmd not found", "sub-mnemonic out of range", etc)

The MOE shall provide the capability to generate, uplink, and verify discrete observatory commands.

Rationale: allows operators to generate and send individual or syntax-based commands

The MOE shall provide the capability to generate command procedures via a user-friendly scripting language.

Rationale: automates the execution of command sequences on the ground that varies based upon observatory state or operator input. See the definition of "procedure" in the glossary.

The MOE shall report the status of command load uplink by the ground station.

Rationale: allows operators to know if a load was uplinked successfully.

The MOE shall support commanding in an autonomous (unattended) state.

Rationale: Provide the capability to run autonomous operations.

3.2.4 Load Generation

The MOE shall provide the capability to uplink observatory loads that are stored as named files in the system. These loads may be memory or command loads.

Rationale: Provides the capability to create and store a load for use at anytime.

The MOE shall provide the capability to generate and store command loads using a file naming convention for time-tagged stored command sequences using absolute time tags.

Rationale: Provide the capability to build and store ATS Command Loads.

The MOE shall provide a capability to generate and store command loads using a file naming convention for time-tagged stored command sequences using relative time tags.

Rationale: Provide the capability to build and store RTS Command Loads.

The MOE shall provide a capability to generate and store table loads using a file naming convention from user input information.

Rationale: Provide the capability to build and store Table Loads.

The MOE shall provide the capability to generate and store command loads using a file naming convention from de-conflicted observatory activity schedules.

Rationale: This Master Schedule forms the basis of command input for ATS command load creation.

The MOE shall allow the user to specify the ATS command load start and stop times available in the observatory activity schedule.

Rationale: The start and end times are specified for every ATS load.

The MOE shall provide the capability to generate and store memory loads using a file naming convention to upload/implement Flight Software (FSW) memory modifications and updates.

Rationale: ability to load and/or modify FSW on the observatory

The MOE shall be capable of generating and storing command loads using a file naming convention to execute and control observatory attitude and orbit maneuvers.

Rationale: maneuver command capability

The MOE shall produce a load generation report for all loads, containing accounting information, description of load contents, any warning and/or error messages and a summary of creation results.

Rationale: For successful creation attempts, a description of each load file on the system will be available. For failed attempts, the report will indicate the problems.

The MOE shall provide the capability to allow authorized operators to edit command loads.

Rationale: The MOE shall provide the capability to deny unauthorized operators access to system capabilities.

The MOE shall provide the capability to allow operators to display command loads in hex and interpreted formats.

The MOE shall provide the capability to report the status of command load generation.

Rationale: allows operators to know the state of command loads that may each be in different stages of development and to know the completion status of automated processing steps. Users are notified of any problems detected by the system during creation of the load.

The MOE shall provide the capability to allow only authorized operators to transfer and/or delete load files.

Rationale: The MOE shall provide the capability to deny unauthorized operators access to system capabilities.

The MOE shall provide the capability to configuration manage load files within the system to preclude the uplink of unapproved load files.

Rationale: provide mechanisms to segregate test or in-work load files from those authorized for uplink.

3.2.5 Hazardous / Critical Command Management

The MOE shall provide the capability to identify and designate critical commands in the command database.

Rationale: flagging of commands that could jeopardize the health and safety of the observatory or its subsystems, under certain conditions.

The MOE shall employ at least one additional operator confirmation prior to the use of a critical command in a command load or in real-time commanding.

Rationale: creates operator intervention for critical commands; Ensures that operator has to provide additional approval before command is used in a command load or in real-time.

The use of additional operator confirmation(s) prior to critical commanding shall be enabled and disabled via system parameter and/or command.

Rationale: Provides support for autonomous commanding, operator and/or procedure may manage this system parameter. The parameter is to be accessible for display and evaluation by procedure. Value is set to enable by default at system startup.

The MOE shall provide the capability to identify and designate hazardous commands in the command database.

Rationale: flagging of commands that may endanger the safety of human beings working on the observatory during I&T, launch preparation or launch.

The MOE shall employ at least one additional operator approval or rejection step prior to the removal of critical and hazardous command designations in the command database.

Rationale: creates operator intervention for removal of hazardous and critical command flags

3.2.6 Constraint Checking

The MOE shall be capable of performing automatic constraint and rule checking of discrete commands and command loads.

Rationale: perform routine check of commands before transmission

The MOE shall be capable of performing manual constraint and rule checking of discrete commands and command loads.

Rationale: operator can invoke an evaluation of a candidate script or schedule

The MOE shall provide the capability to modify or edit command rules and constraints.

The MOE shall identify the item failing constraint check and the constraint that was violated via event messages.

Rationale: notify the operator of the problem and where it is

The MOE shall require at least one additional operator confirmation prior to the transmission of commands or command sequences that have failed constraint check.

Rationale: The capability to preclude transmission of commands or command sequences that have not been constraint or rule checked shall be enabled and disabled by system parameter and/or command.

3.2.7 Command Verification

The MOE shall be capable of notifying the operator that the commands sent to the observatory were correctly received utilizing COP-1 verification.

Rationale: Assess and report 'command verification (CV)' status

The MOE shall provide for operator enable / disable of the command verification function.

Rationale: be able to turn telemetry verification on and off via ground system directive.

The MOE shall be capable of notifying the operator that the commands sent to the observatory were correctly received and executed utilizing telemetry verification.

Rationale: Assess and report 'telemetry verification (TV)' status of an issued command by evaluation command database defined TV parameter expected value against current value in telemetry.

The MOE shall provide for operator enable / disable of the telemetry verification function.

Rationale: be able to turn telemetry verification on and off via ground system directive.

The MOE shall provide the capability to manually retransmit commands or command loads that were not accepted by the observatory (CV).

The MOE shall provide the capability to autonomously retransmit commands or command loads that were not accepted by the observatory (CV).

The MOE shall be capable of an operator-specified number of autonomous command retransmission attempts.

Rationale: allow for N number of automatic retransmission attempts before stopping

The MOE shall provide the capability to enable and disable the autonomous command retransmission capability.

Rationale: ability to turn on/off automated retransmission function

3.2.8 Command Project Database

The MOE shall define observatory commands and their characteristics in a command database.

The MOE shall have the capability to search and sort observatory commands defined in the command database.

Rationale: allows for ease in building command sequences

The MOE command database shall allow the referencing of commands and command sequences based on mnemonic specification.

Rationale: provides logical IDs for commands

The MOE shall provide the capability for authorized user to edit and modify the command database.

Rationale: permits the addition, deletion, editing of entries, fields and attributes

Authority to modify command database shall be controlled by login attributes.

Rational: provides ability to assign different edit privileges to different personnel.

3.2.9 Command Support

The MOE shall archive all command operations and command history for the life of the mission in raw (hex) and interpreted formats.

Rationale: This archive includes all command messages issued to the observatory and provides a time-tagged history of all commands sent to observatory

3.3 Telemetry Processing and Reporting

This section defines the requirements for telemetry processing by the MOE software. Processing the data includes extracting data from the source packets, assessing quality, calibrating, converting, and limit sensing individual telemetry parameters as defined in the project telemetry database. Output, including display, of state conversions, conversion to engineering units and raw value options are required.

3.3.1 Telemetry Processing

The MOE shall accept telemetry from the observatory in accordance with the following Consultative Committee for Space Data Systems (CCSDS) Recommendations for Space Data Systems Standards:
  131.0-B-1 TM Synchronization and Channel Coding,
  732.0-B-1 AOS Space Data Link Protocol, and
  133.0-B-1 TM Space Packet Protocol.

The MOE shall provide the capability to time tag all data with a UTC time.
Rationale: Allows operator to correlate ground system and spacecraft data.

The MOE shall time tag all ground system data with a time of format TBS.
Rationale: Allows operator to distinguish ground system time from spacecraft time.

The MOE shall time tag all observatory data with an observatory time of format TBS.
Rationale: Allows operator to distinguish ground system time from spacecraft time.

The MOE shall provide the capability to decommutate all housekeeping telemetry based on the telemetry database.
Rationale: establishes that decomutation is driven by a database

The MOE shall have the capability to replay telemetry up to a 20X record-time rate processing all packets received.

The MOE shall provide the capability to replay housekeeping telemetry based on an operator-specified start and stop time and replay rate.

The MOE shall provide the capability to specify the replay of housekeeping telemetry by ground receipt time or spacecraft time.

The MOE shall be capable of processing and reporting all housekeeping telemetry.
Rationale: The MOE may need to process real-time, playback and re-transmitted housekeeping telemetry from various S-band and/or X-band downlink virtual channels. The same packet may be received multiple times.

The MOE shall record and distribute CCSDS formatted housekeeping packets received from one to two sources simultaneously.
Rationale: allows the front end to receive and record data from one or two ground stations. Data is distributed to users as per workstation configuration.

The MOE shall be capable of conducting handoffs between GNE, NASA Ground Network (NGN), and Space Network with overlapping observatory view periods with no loss of data.
Rationale: allows handoff from one ground station to another without significant loss of real-time telemetry.

The MOE shall provide the capability to select a new telemetry source and reinitialize related parameters within 1 (TBR) second.
Rationale: provides the capability to cleanly perform handovers between contacts or quickly transition between processing of real/time and playback telemetry.

The MOE shall perform rudimentary post-processing of telemetry data to generate datasets of continuous time-ordered data.

Post-processing by the MOE shall be controlled by directive, generating datasets over user specified time intervals.

The MOE shall create subsets of data from rudimentary post-processed data by user specified APID list.

3.3.2 Data Quality

The MOE shall assess the quality (TBS) of received spacecraft telemetry packets and report the results of that analysis.

The MOE shall detect corrupted packets and correct, if possible.

The MOE shall process corrected packets.

The MOE shall process or pass uncorrectable frames as per user defined configuration under directive control.

The MOE shall mark all parameters in a processed uncorrectable frame as bad quality data.

The MOE shall be capable of assessing quality of the currently available telemetry parameter value.

The MOE telemetry display shall provide data quality indicators.

The MOE shall perform session monitoring and sequence error checking on active links between ground stations and the MOE.
Rationale: quality checking on link and data transfer during communications

The MOE shall prevent ingest of stale or invalid telemetry.
Rationale: rejection of telemetry that is not in a recognizable format and can not be de-commutated or is de-commutated but contains incorrect/invalid values, etc. Rejects telemetry received that has old time stamps not synchronized with current system time.

The MOE shall provide the capability to notify the operator when stale or invalid telemetry is detected.
Rationale: signals ops team when bad telemetry is detected

The MOE shall assess packet continuity of S-band real-time and playback telemetry.
Rationale: This process would notify the MOC of data drop-outs and provide the information to support re-transmit requests. Continuity of engineering data supports assessment of the real-time downlink and the attitude estimation process.

The MOE shall notify the user of non-continuous packet receipt via event message.

3.3.3 Calibration & Conversion

The MOE shall provide the capability to convert telemetry counts into Engineering Units (EUs) using predefined database conversion operators such as but not excluding: polynomials, equations, lookup, supercom, logarithmic, splines, pseudo, bit ordering, etc..

The MOE shall provide the capability to convert discrete telemetry counts into operator-defined text or numeric values in real time using predefined database conversion operators.

The MOE shall provide the capability to output telemetry counts in raw or converted format.

The MOE shall be capable of providing temporary overrides for polynomial definitions. These modifications shall be performed via directive.
Rationale: Modify polynomial conversion coefficients for test or until database update. These updates ate temporary and only applied to specified workstations and only for the currently active session.

The MOE shall provide the capability to display operator-selected telemetry data in real time.

3.3.4 Limit Processing

The MOE shall provide a capability to verify in real-time that telemetry parameters are within prescribed operating limits.

The MOE shall provide the capability to display telemetry limit flags (states).

The MOE shall provide a capability for operators to temporarily define and/or modify telemetry parameter limit conditions. These modifications shall be performed via directive.
Rationale: temporary changes are intended to be applied only to the local workstation and handle situations where definition or modification is needed without modifying the operational database. These updates ate temporary and only applied to specified workstations and only for the currently active session.

The MOE shall provide an operator-configurable color coding scheme to display telemetry relative to limit ranges.
Rationale: without specifying a particular approach, this requires an easily interpretable limit display to determine spacecraft health and safety, e.g. Red-High (RH), Yellow-High (YH), Green, Yellow-Low (YL), and Red-Low (RL). This is configurable to accommodate various forms of color-blindness.

The MOE shall provide an operator-configurable non-color-coded scheme to display telemetry relative to limit ranges.

Rationale: identification of limit display using fonts, symbols, flashing text etc.

The MOE shall perform conditional limit sensing utilizing two or more sets of defined limits based on a user defined switch parameter value.

Rationale: Provides reliable limit sensing ranges based on defining parameter (telemetry, etc) values.

The MOE shall provide the capability for notification of limit violations only after an operator-specified number of consecutive limit failures.

Rationale: Addresses limit persistence - the ability to set how many consecutive points which exceed the limit values must be received before a limit failure is reported (and the telemetry point's state changed).

The MOE shall provide the capability to generate event messages when limit state transitions occur.

Rationale: Used to notify personnel of any limit violation.

The MOE shall provide a capability to turn ON and OFF all limit checks, groups of limit checks or individual limit checks.

Rationale: Groups would be identified in the telemetry data base (e.g., associating a group of parameters to a particular subsystem).

The MOE shall provide the capability to create observatory reports of telemetry related events, including missing telemetry summaries.

Rationale: These reports summarize the contact activities and results, including data collection statistics, limit violations and summaries.

3.3.5 GSE Telemetry Processing Requirements

The MOE shall provide the capability to ingest and process real-time status/control messages from the GNE.

Rationale: Allows telemetry and command functions to process key status information about the quality of data received in a GNE contact.

The MOE shall provide the capability to ingest and process real-time status/control messages consistent with the Interface Control Document between the Space Network and Customers for Service Management.

Rationale: Allows telemetry and command functions to process key status information about the quality of data received in an SN contact.

3.3.6 Derived Telemetry requirements

The MOE shall provide the capability to generate data parameters using database defined algorithms.

Rationale: This allows the user to derive parameter values based on spacecraft and/or GSE telemetry. The algorithms to be applied are defined in the Project Database.

The MOE shall provide full limit processing capabilities for derived telemetry.

Rationale: user can define limits, have them sensed and reported.

3.3.7 Telemetry Project Database

The MOE shall define observatory telemetry and their characteristics in a telemetry database.

The MOE shall have the capability to search and sort observatory telemetry defined in the telemetry database.

Rationale: allows for ease in defining displays, etc

The MOE telemetry database shall allow the referencing of telemetry based on mnemonic specification.

Rationale: TBS

The MOE shall provide the capability for authorized user to edit and modify the telemetry database.

Rationale: permits the addition, deletion, editing of entries, fields and attributes

Authority to modify telemetry database shall be controlled by login attributes.

Rational: provides ability to assign different edit privileges to different personnel.

3.4 Event Generation and Distribution

The MOE shall time tag all ground system event messages with a UTC time of format TBS.

Rationale: Allows operator to distinguish ground system events from spacecraft events.

The MOE shall interpret space segment event messages with an observatory time of format TBS.

Rationale: Allows operator to distinguish ground system events from spacecraft events.

4 Planning and Scheduling

This section defines the requirements for the MOE responsibilities in planning and scheduling the mission. The responsibilities under this function include the creation and maintenance of a master schedule of all ground and space activities. The historical portion of the schedule is selectively updated to form an "as run" timeline.

Processing requirements include incorporation of observatory and ground segment events, ingest and de-confliction of data collection requirements, creation of detailed ground and observatory activity sequences. This master schedule of activities is subsequently utilized to support ground system management, spacecraft real-time and stored commanding.

4.1 Schedule of Activities

The MOE shall provide the capability to plan and schedule all observatory housekeeping and maintenance activities for the life of the mission.

Rationale: The MOE planning and scheduling system will satisfy the MOE requirements for the life of the mission. The system will be capable of accessing previous schedule and planning into the future.

The MOE shall produce time-ordered activity plans listing all planned activities for the observatory planning window.

Rationale: Provides a timeline of all relevant events, observatory stored commands, observatory real-time commands and ground system directives. This plan is structured to be used by the MOC (i.e. stored command load generation, etc).

4.2 Planning System Inputs

This subsection defines the inputs to the Schedule of Activities.

The MOE shall ingest user specified events derived from the Flight Dynamics mission planning products.

Rationale: Incorporate orbit related events (day/nite, ground station visibilities, CONUS transits, etc) into the master schedule for scheduling of activities and reference.

The MOE shall ingest schedules issued by the GNE, NGN and SN.

Rationale: Provide an electronic interface for incorporation of scheduled network events in the master schedule.

The MOE shall incorporate all resource down times or reserved times into schedule generation events.

Rationale: The system will incorporate knowledge of resource limitations in the schedule as the information becomes available. These events are considered throughout the scheduling process.

The MOE shall convert CAPE-provided activity requests into observatory activities.

Rationale: converts the CAPE-generated scene and any other requests to imaging intervals and/or recorder on/off times, off-nadir, IC downlinks, LTAP8 requests, etc.

The MOE shall provide the capability to incorporate activity requests into an activity plan.

Rationale: requires the inclusion of image collection requests from Cal/Val requests, maneuvers, and other observatory activities into an activity plan as well as a backup emergency capability to include routine & priority imaging requests.

The MOE shall assign a priority value to all MOE incorporated activity requests.

Rationale: to support schedule de-confliction based on a priority scheme.

4.3 Operations

The MOE shall support scheduling of the GNE, NGN and SN.

Rationale: Provide an interface to network scheduling offices for receipt of network schedule and incorporation of scheduled network events in the master schedule.

??The MOE shall plan and schedule observatory imaging intervals.

Rationale: MOE-planned imaging intervals would likely be a default imaging mode or a reserved collection allocation, as driven by chosen ops procedure. ??

The MOE shall provide the capability to automatically update activity plans as activity requests are received.

Rationale: allows automatic update to a plan, if a new request is received during the planning process (prior to scheduling)

The MOE shall automatically process all activity requests that fall into the current scheduling window, when generating a schedule.

Rationale: requires that when a schedule is being generated, all activity requests for the current scheduling period are used as input. i.e. for a 72-hour window, any activity in memory that falls into that 72 hour period will be automatically read

The MOE shall provide the capability to create and modify activity priorities, constraints, and rules.

Rationale: This database is used by the system to de-conflict the activity selection during the observatory schedule.

The MOE shall automatically check for activity constraint and rule violations during schedule generation.

The MOE shall automatically check for resource constraint and rule violations during schedule generation.

The MOE shall not allow commanding of the observatory when the elevation angle from the station to the observatory is less than a configurable command angle limit.

Rationale: provides the capability for the FOT to put a lower limit on contact angles to use for commanding, to avoid low-angle link issues.

The MOE shall provide a capability to notify operators via display, report and log messages of conflicts, activity and resource constraint violations, and activity rule violations during planning and scheduling.

Rationale: Displays and reports are used to support the resolution of conflicts and violations. Log messages alert support personnel to the problem.

The MOE shall provide the capability to automatically schedule all observatory and ground station activities within operational resource constraints.

The MOE shall provide the capability to automatically de-conflict unavailable observatory resources.

Rationale: The system will not schedule utilization of un-available resources.

The MOE shall provide the capability to de-conflict activity requests based on a priority value.

Rationale: The system will use a priority scheme to assist in de-conflicting the schedule.

The MOE shall provide the capability to automatically schedule sequences based on activity requests or trigger events entered into the schedule.

Rationale: The system will schedule activities, as per a defined rule set, with respect to user defined events.

The MOE shall provide the capability to produce a Coordinated Universal Time (UTC) time-based activity schedule in terms of specific start/stop times.

The MOE shall be capable of converting to and from UTC reference time to the observatory reference time.

Rationale: Allows MOE products and processes to be time-tagged in either format

The MOE shall provide the capability to generate a conflict-free activity schedule spanning 72-hours of activity.

Rationale: Supports SMRD Autonomous Operations requirement.

The MOE shall provide the capability to generate a conflict-free activity schedule at least once every 12 hours.

Rationale: Supports SMRD Data Latency requirements for nominal ops.

The MOE shall provide the capability to generate a conflict-free activity schedule in 3.5 hours or less, including operator interaction time.

Rationale: Allows FOT to generate new schedules within 3.5 hours supporting SMRD Data Latency requirements for priority collections

The MOE shall provide the capability to insert into the Schedule of Activities, a contact within 15 minutes of an in-view observatory contact.

Rationale: This capability allows insertion of an added event into the master schedule as late as 15 minutes before the event start for subsequent use in scheduling real-time commands, stored commands (for uplink) and GSE directives.

The MOE shall provide the capability to report activity schedule generation status via display and event messages.

Rationale: Visual indicators and log messages report process completion status, error messages and responses to GSE directives.

The MOE shall provide the capability to manually modify an activity schedule.

The MOE shall correlate scene requests to CFDP file status on-board the observatory and at the GNE.

Rationale: to assess the status of scene collection activity requests.

4.4 Product Generation and Distribution

The MOE shall provide the capability to generate a graphical timeline of activity plans and schedules.

The MOE shall provide the capability to generate operator-defined planning and scheduling reports.

The MOE shall provide a display of planned, currently active and past observatory and ground activities.

Rationale: notification of what has happened, will happen or what is happening in the observatory or ground

The MOE shall produce and deliver user-defined subsets of the Master Working Schedule to the CAPE.

Rationale: provide the CAPE a current version of the schedule for long term and scene scheduling.

The MOE shall produce and deliver user-defined subsets of the Master Active Schedule to the CAPE.

Rationale: provide the CAPE a current version of the schedule committed for execution.

The MOE shall produce and deliver user-defined subsets of the Master Working Schedule to the DPAS.

Rationale: provide DPAS a current version of the schedule for use and archive.

The MOE shall notify users of available schedules by product notification message distribution.

Rationale: notify CAPE, DPAS and other users of product deliveries.

The MOE shall report the completion status of scene requests.

Rationale: to assess the status of scene collection activity requests.

The MOE shall be capable of archiving and recovering all mission planning and scheduling data for the life of the mission.

Rationale: Supports the SMRD Archive requirements by providing operator functions for planning and scheduling data management.

The MOE shall be capable of displaying and printing all mission planning and scheduling data for the life of the mission.

Rationale: Provides for operator access to stored plans and schedules

The MOE shall collect and report data collection statistics.

Rationale: include ACK/NAK counts versus expected number of ACKs; post-pass and long-term report;

4.5 Planning & Scheduling Project Database

The MOE shall provide the capability to create, edit, print and delete sets of command / directive sequences for re-use. Each scheduling sequence shall include:
  a) user-defined ID or name
  b) relative start time of sequence
  c) one or more commands/directives
  d) relative time delays between command/directive executions
  e) zero or more passed parameters

Rationale: this capability supports generation of detailed schedule commands/activities based on activity requests.

5 Trending and Analysis

This subsection defines the MOE requirements for trending and analysis. The MOE will provide the capabilities for operations and engineering support personnel to investigate spacecraft anomalies and evaluate performance in the short & long term. These tasks require the user-controlled extraction of data supporting plot generation, statistical analysis, mathematical manipulation and export for external use.

The MOE shall be capable of ingesting and storing all housekeeping telemetry for trending and analysis.

Rationale: The MOE may need to process real-time, playback and re-transmitted housekeeping telemetry from various S-band and/or X-band downlink virtual channels. The same packet may be received multiple times.

The MOE shall provide the capability to ingest and store all GSE telemetry for the life of the mission.

Rationale: supports ability to perform MOE trending and analysis of all telemetry data

The MOE shall perform limit sensing utilizing a user defined set of parameters and limits.

Rationale: Perform "back-orbit" limit sensing of telemetry.

The MOE shall provide the capability to display operator-selected telemetry data for any operator-specified time interval.

The MOE shall provide the capability to define derived-telemetry via operator-defined equations.

Rationale: Provide the ability to perform mathematical operations on telemetry points to create pseudo-telemetry values.

The MOE shall have the ability to set a sample filter rate for trended telemetry.

Rationale: Provide some user control of output generation times.

The MOE shall provide the capability to display discrete telemetry parameters with operator-defined text or numeric values.

The MOE shall provide the capability to export operator-specified telemetry data to current PC-based media, standard desktop software applications, and via the internet.

Rationale: This capability provides a general interface to the user community, in particular, this capability is required by the Cal/Val group.

The MOE shall be capable of displaying multiple sets of stored telemetry data concurrently for 2 or more operators during nominal operations.

Rationale: allows at least 2 operators to view telemetry at the same time

The MOE shall be capable of generating trending products from real-time telemetry.

The MOE shall be capable of generating trending products from stored telemetry.

The MOE shall be capable of generating statistical products from real-time telemetry.

The MOE shall be capable of generating statistical products from stored telemetry.

The MOE shall provide the capability to generate trending and statistical products for any operator-specified time interval.

The MOE shall be capable of generation of trending and statistical products by 2 or more concurrent operators during nominal operations.

The MOE shall provide the capability to indicate limit values on trending and statistical displays and reports.

The MOE shall provide the capability to generate trending products and statistical products for an operator-defined time period.

The MOE shall provide the capability to both manually and automatically generate trending products and statistical products.
Rationale: Product generation can be under direct operator control, activity schedule or application triggers internally defined (i.e. Time of day or percent data collected, etc)

The MOE shall be capable of generating a trending and statistical product for up to 5 telemetry parameters in 5 minutes (TBC5) or less, from the full set of telemetry data.
Rationale: product performance requirement for the full mission life

The MOE shall display a single requested telemetry value from the full telemetry data set in 2 minutes (TBC6) or less.
Rationale: data retrieval performance requirement for the full mission life

The MOE shall provide a capability to trend basic statistical products including minimum, maximum, mean, and standard deviation values at a minimum.
Rationale: allows feeding of standard statistical products through trending function; support long term trending

The MOE shall provide the capability to display telemetry parameters in either raw or engineering unit (EU)-converted format.

6 Flight Dynamics

The flight dynamics requirements are intended to meet all ground system requirements for orbit and attitude maintenance within the MOC. Real-time capabilities include state of health assessment of on-board orbit estimation and attitude estimation. Off-line capabilities supported include orbit determination, control and prediction, definitive attitude determination and prediction, and attitude sensor calibration.

6.1 Health and Safety Assessment

The MOE shall perform evaluation of on-board derived ephemeris and attitude estimates available in the housekeeping telemetry.

Rationale: assess state of health of the on-board generated flight dynamics data

The MOE shall have the capability to perform real-time evaluation of orbit data using predicted ephemeris and NAV message data in the observatory housekeeping telemetry.

Rationale: to alert operations and image processing of potential poor NAV data

The MOE shall provide the capability to automatically detect and notify MOE operators when the observatory orbital parameters deviate from established limits. Notification shall be by event message and report.

The MOE shall have the capability to perform real-time attitude estimation using raw sensor data in the observatory housekeeping telemetry to the best available accuracy.

Rationale: to alert operations and image processing of potential poor attitude

The results shall be reported via product messages.

Rationale: to alert operations and image processing of potential poor attitude

6.2 Orbit Determination

The MOE shall provide the capability to generate the definitive ephemeris of the observatory at an accuracy of 30m in each axis, 3 (TBR) sigma.

Rationale: value-added processing of GPS ephemeris in telemetry to ensure accuracy required to support image processing.

The MOE shall generate definitive ephemeris for the previous Operations Day, every Operational Day or upon request by GSE directive.

Rationale: Ground processing of observatory-generated ephemeris within ancillary data is required to ensure sufficient accuracy to support planning / acquisition data generation and DPAS image processing. Processing is also used to verify integrity of on-board estimates.

The MOE shall perform gap filling for missing definitive orbit data.

The MOE shall produce and distribute a product message containing the definitive ephemeris file name.

The MOE shall produce, store and deliver definitive ephemeris processing quality reports.

The MOE shall evaluate the definitive ephemeris against the requirements for the Operational Orbit defined in the Spacecraft / Observatory Requirements Document.

The MOE shall evaluate the definitive ephemeris and quality report against user-defined criteria and report any violations via log and event messages.

6.3 Orbit Control

The MOE shall provide the capability to perform observatory maneuver planning for the life of the mission.
Rationale: Capability is required to support SMRD Science Accommodation and Calibration Requirements.

The MOE shall be capable of generating maneuver plans to transfer the observatory from the injection orbit to the operational orbit.
Rationale: Key functionality.

The MOE shall be capable of generating maneuver plans in support of all observatory orbit maintenance, calibration, imaging, and decommissioning activities.
Rationale: Key function and SMRD traceability.

The MOE shall provide the capability to automatically identify and report maneuver constraint violations during maneuver planning using the Operational Orbit defined in the Spacecraft / Observatory Requirements Document.

The MOE shall provide the capability to maintain an observatory ground track to WRS-2 grid within +/- 5 km cross-track at the descending node.
Rationale: key function; SORD traceability

The MOE shall provide the capability to calibrate the observatory thrusters
Rationale: to perform thruster cal using maneuver reconstruction after each burn.

The MOE shall provide the capability to monitor and predict observatory propellant usage throughout the life of the mission.
Rationale: propellant (maneuver planning), etc.

The MOE shall predict a near-term (45-day) sequence of orbit maneuver maintenance events.
Rationale: provide rudimentary planning information to the FOT, data to be ingested into the long-term mission planning schedule.

The MOE shall support End of Life Decommissioning activities.

6.4 Orbit Prediction

The MOE shall provide the capability to propagate the observatory orbit to the following accuracies, assuming a solar flux (F10.7) value of less than 215 (10-22 W/m2/Hz) and no maneuver activity during the propagation interval:

Accuracy of predicted orbit state vectors for the first forty (40) hours shall be no greater than the following (TBC7):
   7 meters (3s) radial
 375 meters (3s) along-track
  10 meters (3s) cross-track
 375 meters (3s) RSS

Rationale: support station acquisition for S & X-band acquisition

Accuracy of predicted orbit state vectors at 72 hours shall be no greater than the following (TBC7):
    12 meters (3s) radial
  1200 meters (3s) along-track
    12 meters (3s) cross-track
  1200 meters (3s) RSS

Rationale: supports maintenance of the WRS-2 path/row transit times reported to the CAPE for scene scheduling

The MOE shall provide the capability to propagate the observatory orbit for operator-defined durations.

Rationale: need for orbit prediction / maneuver planning; parent requirement to predicted ephemeris generation

The MOE shall construct and maintain the initial WRS-2 model defined by LDCM document 427-02-07.

Rationale: provide WRS-2 grid and adjust the definition as necessary.

The MOE shall generate and maintain a WRS-2 path/row to time translation table.

Rationale: accurate timing data that must be provided to the CAPE for image collection planning

6.5 Collision Assessment

The MOE shall produce data necessary to support Conjunction Assessment and COLA activities.

Rationale: deliver observatory orbit data for subsequent analysis

The MOE shall receive data necessary to support Conjunction Assessment and COLA activities.

Rationale: receive object ephemeris data for subsequent analysis

The MOE shall propagate object ephemeris and compare results to predicted observatory ephemeris.
Rationale: perform conjunction analysis

6.6 Attitude Determination

The MOE shall produce data of sufficient quality, continuity and pre-processing to meet ingest requirements of the attitude determination system.
Rationale: Data input files are Level-0 equivalent.

The MOE shall have the capability to generate attitude estimates of accuracy meeting mission requirements from raw sensor data contained in observatory housekeeping telemetry.
Rationale: general capability

The MOE shall be capable of validating the on-board attitude estimates meet mission accuracy requirements.
Rationale: off-line process to verify integrity of the on-board attitude estimation process

The MOE shall have the capability to validate the on-board attitude within 30 minutes of contact termination. This process may be initiated via GSE directive
Rationale: to alert operations and image processing of potential poor attitude on-board attitude estimates

The MOE shall generate attitude history file for the previous Operations Day, every Operational Day or upon request by GSE directive.
Rationale: Ground processing is used to verify integrity of on-board attitude estimates, provide a high-fidelity definitive attitude for propagation by the MOE and provide a corrected attitude for possible use by data processing, etc. See FOS ICD for attitude history file format.

6.7 Attitude Prediction

The MOE shall provide the capability to predict attitude and generate an attitude predict file. This capability shall be invoked by directive and capable of producing predictions up to four weeks in duration.
Rationale: this capability is needed to support sensor calibrations and other attitude related functions

The MOE shall predict star tracker target fields and compare these predicts to star acquisition data available in observatory housekeeping telemetry on an as-needed basis.
Rationale: assess state of health of the star tracker and star catalog.

The MOE shall generate star tracker target predicts over the duration of the attitude predict file.

Rationale: produce star catalogs for the full duration of the input attitude estimation file to support operations and analysis.

The MOE shall generate star tracker availability and interference events at the guide star and tracker level over the duration of the attitude predict file.

Rationale: report any interference reports.

The MOE shall accept a star catalog from an external source and have the ability to maintain and uplink the star catalog.

Rationale: the star catalog may be available

The MOE shall accept a sun, lunar & planetary predict ephemeris from an external source and have the ability to uplink the predicts, if necessary.

Rationale: the SLP ephemeris is needed for sensor intrusion and Cal/Val events

6.8 Attitude Sensor Alignment & Calibration

The MOE shall monitor on-board sensor calibrations and re-calibrate, as necessary to meet absolute attitude accuracy requirements.

Rationale: to assure meeting mission attitude requirements

The MOE shall specify and generate attitude maneuver sequences.

Rationale: generate maneuver sequences supporting attitude and instrument calibration maneuvers

The MOE shall specify and generate attitude sensor calibration maneuver sequences to provide sufficient sensor data to derive sensor alignment & calibration coefficients meeting mission attitude determination requirements.

Rationale: may be coincident with instrument maneuvers

The MOE shall generate maneuver plans in a format that is acceptable for input to the uplink generation process.

Rationale: minimize the requirement for human translation of maneuver sequences

6.9 Attitude Control

The MOE shall be capable of automatically generating off-nadir imaging maneuver plans.

Rationale: Off-nadir requests received from the CAPE

6.10 Product Generation and Distribution

The MOE shall provide the capability to both manually and automatically generate flight dynamics products and subsequently distribute these products.

The MOE shall generate orbit maneuver tables in a format that is acceptable for uplink.

The MOE shall generate attitude sensor calibration tables in a format that is acceptable for uplink.

The MOE shall be capable of accepting and uploading externally-generating attitude sensor calibration data.

The MOE shall have the capability to create and uplink updated Solar and Lunar ephemeris information.

The MOE shall provide a capability to display the observatory orbit and ground tracks based on operator-defined durations.

The MOE shall be capable of ingesting externally-generated observatory ephemeris data.

The MOE shall be capable of exporting ephemeris and attitude data for an operator-selectable time interval to current PC-based media, standard desktop software applications, and via internet.

The MOE shall provide the capability to generate attitude-dependent predicted ground station contact/view periods for the observatory.

The MOE shall incorporate ground station antenna masks in computing predicted station contact/view periods.

The MOE shall provide a capability to generate predicted SN contact/view periods for the observatory.

The MOE shall provide the capability to generate observatory acquisition data for ground stations.

Rationale: provides capability to generate two line elements (TLE), Brouwer mean element (BME) and improved inter range vectors (IIRV) for ground stations.

The MOE shall generate observatory acquisition data for the SN.

Rationale: provides capability to generate two line elements (TLE), Brouwer mean element (BME) and improved inter range vectors (IIRV) for TDRSS.

The MOE shall provide the capability to model sun-line RF interference between the observatory and ground stations, and between the observatory and the SN.

The MOE shall generate and distribute Attitude Validation Reports in response to GSE directive.

Rationale: notify users of potential errors and/or to distribute and control the routine reporting of the attitude validation processes

The MOE shall provide the capability to generate operator-specified flight dynamics and maneuver planning reports.

Rationale: ability to produce products such as view periods, eclipse entrance/exit, ascending/descending node, solar beta angle

The MOE shall report and plot attitude with respect to operator selected reference frames.

Rationale: such as LVLH, J2000 inertial, orbital reference, and earth-fixed

7 Memory Management

This section defines additional requirements supporting observatory memory management. Mechanisms to generate, store and uplink memory modifications was discussed in Section 3 of this document.

7.1 Flight Software Management

(TBS) This subsection needs a reference to a CDRL item between the FOT/USGS and the bus vendor explicitly defining memory segment ownership and delivery mechanisms.

The MOE shall provide version control for Ground Reference Image (GRI) of observatory memory.

Rationale: Required to provide health/status of on-board computers; required to enable reload of flight software executable from ground segment in case of single event upsets or other anomalies.

The MOE shall provide the capability to modify any re-programmable/writeable memory locations on the observatory.

Rationale: SW updates for actuators, sensors, processors, etc.

The MOE shall be capable of exporting observatory memory dump data to current PC-based media, standard desktop software applications, and via internet.

Rationale: Standard requirement to allow effective data management of memory dump data.

The MOE shall provide the capability to compare multiple memory dumps and report the specific differences.

Rationale: Required for OBC memory management.

The MOE shall provide the capability to compare memory dumps with the GRI and report the specific differences.

The MOE shall provide the ability to view the Ground Reference Image.

The MOE shall provide the ability to view observatory memory dumps.

The MOE shall be capable of displaying memory tables in human-readable format.

7.2 Mass Storage Management

The MOE shall generate and assign a unique interval identifier, based on an identifier scheme defined in conjunction with the Government.

Rationale: allows ground to generate the interval ID. Allows data to be tracked through entire LDCM operations and science data processing systems per Level II requirement. Unique interval identifiers will be the same as root file IDs in observatory mass storage for ease in recorder management. See SSRD requirement.

The MOE shall generate and maintain the scene to interval identifier mapping table.

Rationale: since CAPE selects scenes and MOE assigns intervals and root file ID, the MOE must keep track of the linkage between the two. Observatory will assign specific file names based on a scheme defined in conjunction with the Government.

The MOE shall be capable of designating imaging intervals as Priority.

Rationale: The MOE must flag priority intervals so that the ground system can expedite the downlink of the scene/interval. Prioritization of playback data is strictly done on ground. If one scene within a long interval is priority, FOT can schedule that scene as its own interval.

The MOE shall be capable of designating imaging intervals as Protected.

Rationale: The MOE must flag protected scenes or the interval and file it resides in, so that the observatory does not overwrite them. Expect that standard ops will be to protect all data on board until it is downlinked.

The MOE shall be capable of removing the Priority and Protected designations from imaging intervals.

Rationale: Ability to remove flags within the MOE

The MOE shall generate mass storage commands using interval/root file identifier designations.

Rationale: file -based recorder management capability; root file IDs are the same as interval IDs

The MOE shall be capable of generating mass storage commands using memory location designations.

Rationale: capability for location-based recorder management capability, if file naming gets corrupted

The MOE shall have the capability to command data in mass storage to be unprotected.

Rationale: If observatory mass storage contains protected data, the MOE will be able to command files or locations to be unprotected in mass storage and available for overwriting. Expected standard ops are to command data to be unprotected when it has been receipt-acknowledged by ground.

The MOE shall have the capability to set the priority status of mass storage by command..

The MOE shall provide a capability for operators to select data in mass storage for downlink.

Rationale: Allows the ground to determine what files or locations to downlink and re-downlink when.

The MOE shall accept spacecraft SSR state vector telemetry.

Rationale: to support analysis of scene data collection and recovery information

The MOE shall accept GNE CFDP file status data.

Rationale: to support analysis of scene data collection and recovery information

The MOE shall display file directory listings, tables, and dump data in human readable formats.

Rationale: ability for operators to view and interpret tables and dumps

The MOE shall provide the capability to model current and predicted observatory mass storage utilization.

Rationale: Allows MOE to monitor and plan on-board recorder usage

The MOE mass storage modeling capability shall accept observatory data collection and downlink planning and scheduling inputs.

Rationale: future collection and downlink activities must feed model in order to have an accurate representation for planning purposes

The MOE mass storage modeling capability shall accept observatory housekeeping telemetry inputs.

Rationale: to accurately model the state of mass storage, the model should feed from telemetry

The MOE mass storage modeling capability shall provide a textual and graphical display.

Rationale: operators must be able to view and interpret mass storage model data

The MOE mass storage modeling capability shall notify users of results via event messages.

Rationale: operators must be able to view and interpret mass storage model data

The MOE shall provide a configurable capability to automatically commanding the observatory to downlink Priority files first, then the oldest files in mass storage.

Rationale: For unattended operations, the MOE can direct the downlink priority first, then oldest to youngest

The MOE shall automatically maintain a state vector of data file status based on the schedule, observatory real-time telemetry, GNE data receipt messages.

Rationale: This capability provides a current assessment of data status used for autonomous ground management of data retransmission or unprotect.

The MOE shall provide a configurable capability to automatically command the retransmission of data files based on the status received from the GNE.

Rationale: This capability allows autonomous commanding of data retransmission, thus achieving a class 2 service outcome as defined in the CCSDS CFDP standard.

The MOE shall provide a reconfigurable capability to automatically command the observatory to unprotect files in mass storage based on the status received from the GNE.

The MOE shall generate a playback data accounting summary for each observatory downlink session supported, to include the following information:
 a) File name of each file received
 b) data type/source (want this to be part of file name)
 c) byte-size for each file
 d) File Acknowledgement Flag
 e) number of pending File Retransmission Requests buffered for this pass.

8   General / Administrative

The MOE shall conform to NPD 8010.2D, NASA Policy Directive, Use of the SI (Metric) System of Measurement in NASA Programs.

The MOE shall provide the capability to maintain version control for all MOE data.

The MOE shall provide the capability to produce and store data and products in a tabular, plot, textual, and graphics form
Rationale: generates and saves reports in product form

The MOE shall provide the capability to generate reports.

The MOE shall provide the capability to save and retrieve any report.

The MOE shall provide the capability to generate operator-defined reports and products based on operator-provided scripts.

The MOE shall provide the capability to generate one-time and regularly recurring reports and products at times indicated by operator-provided scripts.

The MOE shall provide the capability to print all data displayable on a workstation.

The MOE shall provide an anomaly reporting and status tracking capability.

The MOE shall be automatically synchronized to a GFE-provided external master time signal reference.
Rationale: Allows time across the various MOE systems to be synchronized with a time source that stays accurate without operator intervention. This ensures that ground timestamps on data, event logs, etc. remains accurate.

8.1   Security & Access Control

All MOE capabilities shall comply with NPR 2810.1A, NASA Procedural Requirement, Security of Information Technology.

The MOE shall log all security events for the life of the mission, including successful and unsuccessful system access attempts, and file creations, deletions, and modifications.

The MOE shall provide individual operator account and password controls for access to the system and use of the software.

The MOE shall have the capability to restrict operator access compliant with NPR 2810.1A.
Rationale: all applications will require userid / password authentication before allowing access.

The MOE remote access interface shall be password protected.

Rationale: Satisfies basic security requirements levied/described in NPR 2810.1A. Reduces probability of telemetry pages being accessed by unauthorized personnel.

The MOE shall provide the capability to assign access privileges by login identification based on user defined input.

Rationale: Provides for controlled access to application capabilities.

The MOE shall comply with the following subparts of Section 508 of the Rehabilitation Act (29 U.S.C. 749d), as amended, 36 CFR Part 1194: Subpart A, Subpart B 1194.21, 1194.22, 1194.26, Subpart C, and Subpart D.

Rationale: compliance with accessibility requirements for software and selected hardware; also compliance with requirement from NPR 7150.2

9 Event and Logging Operations

This section defined the general requirements for event message generation, distribution and handling.

The MOE shall publish copies of user selected log messages to a centralized log.
Rationale: a comprehensive time ordered sequence of events will be available showing events from all applications

The MOE shall have the capability to display and archive the centralized log.
Rationale: support user access of the log

The MOE shall provide the capability for operators to create and modify the conditions when event messages are generated.
Rationale: ability to modify event conditions in the database

The MOE shall provide the capability for operators to create and modify the content of event messages.
Rationale: ability to modify event message text in the database

The MOE shall time tag all event messages with a UTC time.
Rationale: Allows operator to correlate ground system and spacecraft events.

The MOE shall time tag all ground system event messages with a UTC time of format TBS.
Rationale: Allows operator to distinguish ground system events from spacecraft events.

The MOE shall interpret space segment event messages with an observatory time of format TBS.
Rationale: Allows operator to distinguish ground system events from spacecraft events.

The MOE shall provide an operator-configurable color coding scheme to display event messages.
Rationale: without specifying a particular approach, this requires an easily interpretable means of identifying alarms, warnings and routine messages, e.g. Red for alarms, yellow for warnings, blue for routine messages, etc. This is configurable to accommodate various forms of color-blindness.

The MOE shall provide an operator-configurable non-color-coded scheme to display event messages.
Rationale: This is identification of event message displays using fonts, symbols, flashing text etc.

The MOE shall provide the capability to generate operator-defined event message reports.

The MOE shall allow the operator to enable, disable, filter, and display event messages.

The MOE shall provide an operator-configurable control to filter repeated event messages.

Rationale: Allows operator to prevent the same event message from occurring over and over in the event log. You may not want the same limit violation repeated over and over again, but rather on every nth occurrence

The MOE shall provide the capability to log all event messages for the life of the mission.

The MOE shall provide the capability to display any event messages and logs.

The MOE shall provide a capability to generate and save operator logs.

Rationale: keep a record of operator interaction with the system

10 Operator Interface

The MOE shall have the capability to provide video output of any workstation display to 3 or more workstations and/or video projection devices.

Rationale: provide the capability to project, for the general audience, user-selected displays

The MOE shall provide the capability for the operator to define and display customizable views of data and graphics.

The MOE shall be capable of utilizing a Graphical User Interface (GUI) for system operation.

The MOE shall be capable of utilizing a command line interface.

The MOE shall provide the capability for a secure remote web interface for real-time telemetry, trending and analysis, and event/messaging MOE capabilities for at least 20 concurrent operators.

Rationale: facilitates support from ops and engineering personnel who are remotely-located from the MOC

During launch and early orbit, the MOE shall be capable of providing trending and analysis functionality for at least 10 concurrent operators.

Rationale: Of 20 total operators, 10 for sub-system and instrument support engineers/experts

During launch and early orbit, the MOE shall be capable of providing command and control, planning and scheduling, and flight dynamics functionality for at least 10 concurrent FOT operators.

Rationale: Of 20 total operators, at least 10 have the appropriate concurrent commanding, planning & scheduling, and flight dynamics functionality to support L&EO.

The MOE shall provide the capability to route hardcopy output to a user selected output device.

Rationale: MOC to support at least two or more printers of which the user can select from.

11 Automation

This subsection defines the requirements levied on the MOE for support of autonomous operations during normal mission operations. The MOE will provide tools to perform routine and periodic operations autonomously.

All functional applications in the MOE shall have the ability to run unattended while performing all routine and periodic operations for 96 hours.

Rationale: supports autonomous operations during 3-day weekend; assume schedules have already been made and command loads generated prior to going into autonomous mode.

All the applications in the MOE must be able to be managed via directives.

Rationale: running from directives generated via command line, application, activity schedule, etc.

All MOE applications shall generate and publish event messages providing alarm / warning / event information to indicate application state.

Rationale: Event messages shall be evaluated and responded to as defined by user.

The MOE shall provide the capability to autonomously distribute all products on a time or activity schedule basis.

Rationale: Minimizes operation intervention in the data distribution process.

The MOE shall be capable of autonomously establishing a command and telemetry link with an GNE station for every observatory-GNE contact.

Rationale: autonomy needed for unattended operations

The MOE shall be capable of ingesting CAPE input, scheduling and generating command loads automatically, when scheduled to do so by an operator.

Rationale: This is intended to support revision of data collection based on updated cloud cover predictions at CAPE in an autonomous mode.

The MOE shall utilize a service-oriented architecture (SOA).

Rationale: LDCM desires open architecture for extensibility, scalability, simplification of I&T, and autonomous operations

The MOE shall be capable of adding and removing MOE sub-systems with no loss in data or interruption to operations.

Rationale: enables modularity and scalability, plug and play architecture

The MOE shall provide standardized interfaces between sub-systems.

Rationale: enables modularity and scalability, plug and play architecture

The MOE shall provide standardized message-based communications between MOE sub-systems and applications.

Rationale: supports modularity, situational awareness, and autonomous operations

The MOE sub-systems and applications shall automatically respond to start, stop, pause, heartbeat, and directive requests.

Rationale: basic level of support for all applications in the autonomous environment

The MOE shall provide the capability to monitor and report message traffic, system health status, and system configuration among and between MOE sub-systems.

Rationale: monitor communications between MOE functions in service oriented architecture (SOA) environment and provide status of MOE equipment and software (situational awareness)

The MOE shall be capable of generating alert notifications remotely to a communications/pager service.

Rationale: Notifying personnel in response to user selected ground system events.

The MOE shall incorporate user definable call lists and schedules to perform the notifications.

Rationale: Allows the user to maintain the call list.

The MOE shall provide for notification trigger message filtering, rudimentary wildcard trigger selection, and Nth occurrence filtering.

Rationale: to provide basic mechanisms to minimize invalid and excessive notifications.

12 Availability and Redundancy

A controlled 'power-down' and 'power-on initialization' sequence for all the MOE subsystems and applications shall be complete in less than 30 minutes.

Rationale: All MOE subsystems may be power cycled or re-booted between contacts.

The MOE shall provide system monitoring tools to track MOE system performance.

The MOE shall have a system up time availability for command and control operations of at least 99.9% (TBC9) averaged over 30 days, not including planned maintenance during non-contact time periods.

Rationale: MOE must be available to support around the clock observatory operations; excludes maximum total planned down time per month for performance of system maintenance

The MOE, excluding command and control operations, shall have a system up time availability of 99.5% averaged over 30 days, not including planned maintenance conducted during non-contact periods.

Rationale: MOE systems, non-critical to command and control, can have a less stringent up-time availability, and be scheduled for maintenance on a non-interference basis to mission operations.

The MOE shall have a mean time to restore critical command and control operations of 1 minute (TBC10) or less.

Rationale: This provides for the transfer of command gateway authority from one workstation to another in the event of failure, ensures no loss of ability to command, control, and ingest telemetry

The MOE shall provide the capability to support training, testing, or system maintenance with no interruption to MOE functionality.

Rationale: to support training (including simulation), testing, and system maintenance and use of the observatory simulator on a non-interference basis.

The MOE shall be capable of operating with the observatory simulator concurrently with mission operations, with no impact to mission operations.

Rationale: specifically creates ability to use simulator while performing mission ops

The MOE shall provide the capability to log, track, and report system faults and failures.

The MOE shall provide the capability to report system faults and failures remotely to a communications/pager service

13 Backup MOE (bMOE)

This subsection defines requirements in support of the backup MOE. The bMOE will be housed in the backup MOC (bMOC). This facility will serve a variety of functions throughout the mission. As such, the size and physical location of the bMOE deployment may vary. The bMOE delivery requirements are listed in Section 14. Transfer of FOT products sufficient and necessary to continue operations from any supported facility will be via a designated repository physically located outside of the MOC.

The bMOE shall provide all the capabilities of the MOE as described in sections 3 through 12 of this document.

Rationale: the backup MOE provides all the functionality of the MOE. Note that section 14.12 specifies bMOE interface requirements.

The primary MOE shall communicate bi-directionally with the bMOE for data transfer, synchronization, and check-pointing whenever the bMOE is activate.

Rationale: During checkout, maintenance and parallel operations, the system will assess synchronization of the MOE and bMOE, reporting any deviations in configuration and database, and providing mechanisms to support automated or manual re-synchronization.

The MOE shall be capable of transferring critical command and control data and information to the bMOE or designated repository, a minimum of once per 8 hour period.

Rationale: ensures current copies of the Project Databases and other critical ops information is available to the bMOC and consistent between MOE and bMOE.

The MOE shall be capable of critical command and control data and information transfer to the bMOE or designated repository within 1 hour from the start of the transfer.

Rationale: establishes time for updating bMOE databases and information

The bMOE shall be capable of transferring critical command and control data and information to the MOE or designated repository, a minimum of once per 8 hour period.

Rationale: when bMOE is serving as primary, ensures current copies of the Project Databases and other critical ops information is available to the MOC and consistent between MOE and bMOE..

The bMOE shall be capable of critical command and control data and information transfer to the MOE or designated repository within one hour from the start of the transfer.

Rationale: establishes time for updating MOE databases and information, when bMOE is serving as primary

14 Interfaces

This section contains the MOE interface requirements. Figure 14-1 illustrates the MOE interfaces in the context of the overall LDMC mission and interfaces.
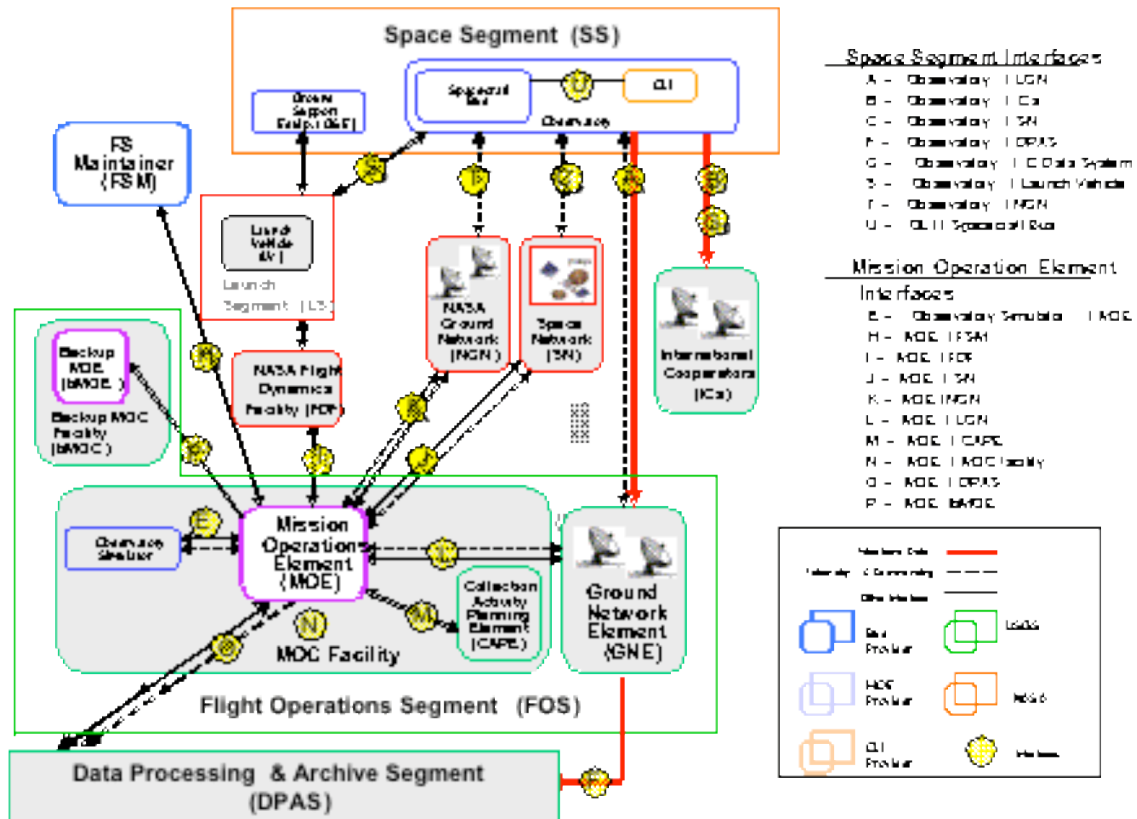

Figure 14-1: Mission Operations Element Interfaces

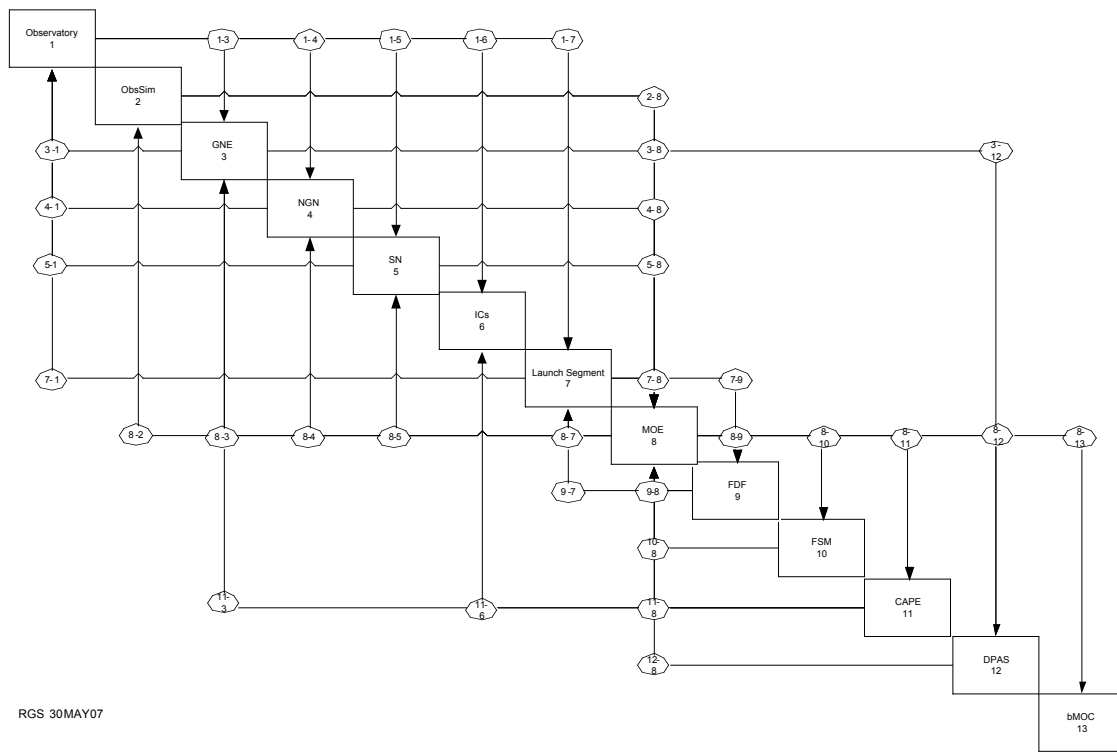Figure 14-2 provides a N2 diagram of the MOE interfaces.

Figure 14-2: Mission Operations Element N2 Diagram

Table 14-1 provides a tabular summary of the Moe related traffic across the nodes as defined in Figure 14-2.

Product Name	From/To	N2	ICD	Data Type	Frequency	Duration	Schedule
Observatory Real-time Mission Data	Observatory / GNE	1-3	1: Sec 16.1	X-band	Each contact	Full contact	Real-time
Observatory Stored Mission Telemetry	Observatory / GNE	1-3	1: Sec 16.1	X-band	Each contact	Full contact	Real-time
Observatory Real-time Housekeeping Telemetry	Observatory / GNE	1-3	1: Sec 16.1	S-band	Each contact	Full contact	Real-time
Observatory Stored Housekeeping Telemetry	Observatory / GNE	1-3	1: Sec 16.1	S-band	Each contact	Full contact	Real-time
Observatory Real-time Housekeeping Telemetry	Observatory / NGN	1-4	1: Sec 16.2	S-band	Each contact	Full contact	Real-time
Observatory Stored Housekeeping Telemetry	Observatory / NGN	1-4	1: Sec 16.2	S-band	Each contact	Full contact	Real-time
Observatory Real-time Housekeeping Telemetry	Observatory / SN	1-5	1: Sec 16.3	S-band	Launch & Contingrncy	Full contact	Real-time
Observatory Real-time Mission Data	Observatory / ICs	1-6	1: Sec 16.4	X-band	Each contact	Full contact	In-view
Observatory RF	Observatory / LS	1-7	1: Sec 4.8	S-band (TBR)	As required	As required	Pad
Observatory Prop SOH	Observatory / LS	1-7	1: Sec 4.8	GSE data	As required	As required	Pad
Observatory PWR SOH	Observatory / LS	1-7	1: Sec 4.8	GSE data	As required	As required	Pad
Observatory HL Data	Observatory / LS	1-7	1: Sec 16.5	GSE data	As required	As required	Pad
Observatory Real-time Mission Data	ObsSim / MOE	2-8		X-band	As required	As required	Real-time
Observatory Stored Mission Telemetry	ObsSim / MOE	2-8		X-band	As required	As required	Real-time
Observatory Real-time Housekeeping Telemetry	ObsSim / MOE	2-8		S-band	As required	As required	Real-time
Observatory Stored Housekeeping Telemetry	ObsSim / MOE	2-8		S-band	As required	As required	Real-time
Observatory Commands	GNE / Observatory	3-1	1: Sec 16.1	RT Commands	As required	As required	Real-time
Observatory Real-time Housekeeping Telemetry	GNE / MOE	3-8		S-band	Each contact	Full contact	Real-time
Observatory Stored Housekeeping Telemetry	GNE / MOE	3-8		S-band	Each contact	Full contact	Near-Real-Time
Network Schedule	GNE / MOE	3-8		ASCII file data	Once per week	Three weeks	Noon Wednesday
GNE GSE Data	GNE / MOE	3-8		GSE data	Each contact	Full contact	Full contact
X-band Data Status Messages	GNE / MOE	3-8		GSE data	Each contact	Full contact	Post-pass
X-band Data Messages	GNE / DPAS	3-12		X-band	Each interval	Full interval	Off-line

Table 14-1: Mission Operations Element Node Summary (1 of 3)

Product Name	From/To	N2	ICD	Data Type	Frequency	Duration	Schedule
Observatory Commands	NGN / Observatory	4-1	1: Sec 16.2	RT Commands	As required	As required	Real-time
Observatory Real-time Housekeeping Telemetry	NGN / MOE	4-8		S-band	Each contact	Full contact	Real-time
Network Schedule	NGN / MOE	4-8		ASCII file data	Once per week	Three weeks	Noon Wednesday
Observatory Commands	SN / Observatory	5-1	1: Sec 16.3	RT Commands	As required	As required	Real-time
Observatory Real-time Housekeeping Telemetry	SN / MOE	5-8		S-band	Each contact	Full contact	Real-time
Network Schedule	SN / MOE	5-8		ASCII file data	Once per week	Three weeks	Noon Wednesday
1-way Ranging	SN / FDF	5-9		GSE data	Launch & Contingrncy	Full contact	Real-time
Observatory Power	LS / Observatory	7-1	1: Sec 4.8	N/A	As required	As required	Pad
GPS Data	LS / Observatory	7-1	1: Sec 4.8	GSE data	As required	As required	Pad
Observatory Commands	LS / Observatory	7-1	1: Sec 16.5	RT Commands	As required	As required	Pad
Observatory Commands	ITF & LS / Observatory	7-1	1: Sec 16.1	RT Commands	As required	As required	Real-time
Observatory Real-time Housekeeping Telemetry	ITF & LS / MOE	7-8		S-band	Each contact	Full contact	Real-time
Observatory Stored Housekeeping Telemetry	ITF & LS / MOE	7-8		S-band	Each contact	Full contact	Near-Real-Time
ITF & LS GSE Data	ITF & LS / MOE	7-8		GSE data	Each contact	Full contact	Full contact
ITF & LS Databases	ITF & LS / MOE	7-8		PDB data	As required	As required	As required
Observatory Commands	MOE / ObsSim	8-2		RT Commands	As required	As required	Real-time
Network Schedule Requests	MOE / GNE	8-3		ASCII file data	As required	As required	Real-time
Observatory Commands	MOE / GNE	8-3		RT Commands	As required	As required	Real-time
Acquisition Data	MOE / GNE	8-3		Network Acquisition Data	M-F	7 days	Start of work day
LGN GSE Directives	MOE / GNE	8-3		GSE Data	As required	As required	As required
Network Schedule Requests	MOE / NGN	8-4		ASCII file data	As required	As required	Real-time
Observatory Commands	MOE / NGN	8-4		RT Commands	As required	As required	Real-time
Acquisition Data	MOE / NGN	8-4		Network Acquisition Data	M-F	7 days	Start of work day
Network Schedule Requests	MOE / SN	8-5		ASCII file data	As required	As required	Real-time
Observatory Commands	MOE / SN	8-5		RT Commands	As required	As required	Real-time
Acquisition Data	MOE / SN	8-5		Network Acquisition Data	M-F	7 days	Start of work day

Table 14-1: Mission Operations Element Node Summary (2 of 3)

Product Name	From/To	N2	ICD	Data Type	Frequency	Duration	Schedule
Observatory Commands	MOE / ITF & LS	8-7		RT Commands	As required	As required	Real-time
ITF & LS Databases	MOE / ITF & LS	8-7		PDB data	As required	As required	As required
Definitive Ephemeris	MOE / FDF	8-9		Data Processing	As required	As required	As required
Maneuver Planning Data	MOE / FDF	8-9		Special Event	As required	As required	Delta V - TBS hrs
FSW Data	MOE / FSM	8-10		Data Processing	As required	As required	As required
Forcast Schedule	MOE / CAPE	8-11		Events, RT & Stored Cmds, Directives	Once per week	Twenty-one (21) days	By COB Wednesday
Master Working Schedule	MOE / CAPE	8-11		Events, RT & Stored Cmds, Directives	Once per day	72 hours	Start of work day
Master Active Schedule	MOE / CAPE	8-11		Events, RT & Stored Cmds, Directives	Once per day	72 hours	Upon uplink to observatory
Planning Data	MOE / CAPE	8-11		Mission Planning data	Daily	Thirty (30) days	Start of work day
Acquisition Data	MOE / CAPE	8-11		Network Acquisition Data	M-F	7 days	Start of work day
Notification Messages	MOE / CAPE	8-11		Notification System	As required	As required	As required
Definitive Ephemeris	MOE / DPAS	8-12		Data Processing	Daily	Previous Op Day	Start of work day
Definitive Attitude	MOE / DPAS	8-12		Data Processing	Daily	Previous Op Day	Start of work day
S-band Archive (RT & PLBK)	MOE / DPAS	8-12		Data Processing & Ops Access	Each contact	Full contact	Post-pass
Forcast Schedule	MOE / DPAS	8-12		Events, RT & Stored Cmds, Directives	Once per week	Twenty-one (21) days	By COB Wednesday
Master Working Schedule	MOE / DPAS	8-12		Events, RT & Stored Cmds, Directives	Once per day	72 hours	Start of work day
Master Active Schedule	MOE / DPAS	8-12		Events, RT & Stored Cmds, Directives	Once per day	72 hours	Upon uplink to observatory
Notification Messages	MOE / DPAS	8-12		Notification System	As required	As required	As required
FOT Products	MOE / bMOC	8-13		Mission Planning data	Daily	Thirty (30) days	Start of work day
Definitive Ephemeris	FDF / MOE	9-8		Data Processing	As required	As required	As required
Predicted Ephemeris	FDF / MOE	9-8		Data Processing	As required	As required	As required
FSW Data	FSM / MOE	10-8		Data Processing	As required	As required	As required
Acquisition Data	CAPE / IC	11-6		Network Acquisition Data	Daily	7 days	Start of work day
CAPE Data Collection Schedule	CAPE / MOE	11-8		Events, RT & Stored Cmds, Directives	Once per day	72 hours	End of work day
Cal / Val Request	CalVal / UPE	14-11		Mission Planning data	As required	15 min (solar) / 1 orbit (lunar)	weekly

Table 14-1: Mission Operations Element Node Summary (3 of 3)

The MOE shall interface with external interfaces as specified in the LDCM Mission Operations Element Interface Control Document.

Rationale: this section of the MOE RD identifies the external elements the MOE will interface to and the general types of communication required.

14.1 LDCM Observatory

The MOE shall generate commands for transmission to the observatory.

The MOE shall accept housekeeping telemetry from the observatory.

14.2 LDCM Observatory Simulator (ObsSim)

The MOE shall generate commands for transmission to the observatory simulator.

The MOE shall accept housekeeping telemetry from the observatory simulator.

14.3 LDCM Ground Network Element (GNE)

The MOE shall support S-band and X-band operations with the GNE

The MOE shall send scheduling requests to the GNE.

The MOE shall receive scheduling data/information from the GNE.

The MOE shall provide acquisition data to the GNE.

The MOE shall send forward and return link service requests to the GNE.

The MOE shall receive forward and return link service request responses from the GNE.

The MOE shall send observatory commands to the GNE for S-band uplink.

The MOE shall receive real-time S-band housekeeping telemetry from the GNE.

The MOE shall receive S-band stored housekeeping telemetry from the GNE.

The MOE shall receive return link quality information from the GNE.

The MOE shall receive data from the GNE to support X-band data recovery.

14.4 NASA Ground Network (NGN)

The MOE shall support S-band operations with the NGN.

The MOE shall send scheduling information and acquisition data to the NGN as defined in the Ground Network User's Guide.

The MOE shall receive scheduling data/information from the NGN as defined in the Ground Network User's Guide.

The MOE shall provide acquisition data to the NGN.

The MOE shall receive real-time housekeeping telemetry from the NGN.

The MOE shall receive stored housekeeping telemetry from the NGN.

The MOE shall send observatory commands to the NGN.

The MOE shall receive pass reports from the NGN as defined in the Ground Network User's Guide.

14.5 NASA Space Network (SN)

The MOE shall support S-band operations with the SN.

The LDCM MOC will interface to the SN for scheduling purposes using a Government-provided, SN-compatible scheduling system. The SN-compatible schedule system will be separate from the MOE. Scheduling information will be transferred between the SN and MOC consistent with the Interface Control Document between the Space Network and Customers for Service Management.

The MOE shall provide acquisition data to the SN.

The MOE shall send forward and return link service Ground Control Message Requests (GCMRs) to the SN, consistent with the Interface Control Document between the Space Network and Customers for Service Management.

The MOE shall receive real-time network status/control messages from the SN, consistent with the Interface Control Document between the Space Network and Customers for Service Management.

The MOE shall receive real-time housekeeping telemetry from the SN.

The MOE shall receive stored housekeeping telemetry from the SN.

The MOE shall send observatory commands to the SN.

14.6 International Cooperators (IC)

The MOE shall generate acquisition data for the ICs.

14.7 Observatory at Integration and Test Facility (ITF) and Launch Segment (LS)

The MOE shall support S-band and X-band operations with the ITF and LS

The MOE shall send observatory commands to the observatory.

Rationale: The MOE must be able to send commands to the observatory while it is at the observatory I&T facility and at the launch site.

The MOE shall receive housekeeping telemetry from the observatory.

Rationale: The MOE must be able to receive telemetry from the observatory while it is at the observatory I&T facility and at the launch site.

The MOE shall receive mission telemetry from the observatory.

Rationale: The MOE must be able to receive telemetry from the observatory while it is at the observatory I&T facility and at the launch site.

The MOE shall receive GSE data from the ITF and LS.

Rationale: The MOE must be able to receive and process GSE data.

The MOE shall send database information to the Integration & Test Facility and the Launch Site.

Rationale: MOC developed databases can be transferred to the remote MOE for review and evaluation. This interface may require a re-formatting of the information by the MOE.

The MOE shall receive and accept database information from the Integration & Test Facility and the Launch Site.

Rationale: I&T developed databases can be transferred to the MOE for review and evaluation. This interface may require a re-formatting of the information by the MOE.

14.8 Mission Operations Center (MOC) Facility

The MOE shall receive an external IRIG-B (TBC11) master time signal reference from the MOC facility.

The MOE shall receive a fire walled public Internet connection from the MOC facility.

14.9 NASA Flight Dynamics Facility (FDF)

The MOE shall send predicted ephemeris to the FDF.

Rationale: supports Earth Science Mission Operation (ESMO) a.m. constellation coordination activities, and conjunction assessments.

The MOE shall receive LDCM definitive ephemeris data from the FDF.

Rationale: for anomaly resolution, FDF provides tracking data for GNE stations

The MOE shall receive predicted observatory ephemeris from the FDF.

Rationale: during launch and early orbit; FDF provides based on state vectors at LV separation; allows MOE to make contact with observatory

14.10 Flight Software Maintainer (FSM)

The MOE shall send table data to the FSM.
Rationale: to support flight software changes

The MOE shall send memory dump data to the FSM.
Rationale: to allow the FSM to see what is actually on-board, which may need to be compared to what the FSM thinks is on-board.

The MOE shall receive flight software updates from the FSM.

The MOE shall receive table data from the FSM.
Rationale: to support flight software changes

14.11 Collection Activity Planning Element (CAPE)

The MOE shall send time-based resource availability, configuration and status data to the CAPE.
Rationale: observatory and ground system information needed for image collection planning

The MOE shall send MOE system status information to CAPE.

The MOE shall send observatory contact opportunities (including projected downlink opportunities, uplink opportunities, and lunar calibration opportunities) to CAPE.

The MOE shall send the WRS path/row to time translation table to the CAPE.
Rationale: timing needed for image collection planning

The MOE shall receive collection requests from the CAPE.

The MOE shall receive calibration requests from the CAPE.

The MOE shall receive scene management requests from the CAPE.

The MOE shall send plans and schedules to the CAPE.

The MOE shall send IC downlink schedules to the CAPE.

The MOE shall send scene ID to interval ID mapping tables to the CAPE.
Rationale: the MOE generates interval IDs, and the CAPE needs these to track data throughout the rest of the system.

14.12 Data Processing and Archive Segment (DPAS)

The MOE shall send housekeeping data to the DPAS within 12 hours of receipt at MOE.
Rationale: DPAS keeps a copy of housekeeping data for easy access by cal/val teams

The MOE shall send plans and schedules to DPAS.

The MOE shall provide notification messages to DPAS.

The MOE shall provide definitive ephemeris data to DPAS.

14.13 Backup MOE (bMOE)

The MOE and bMOE shall exchange data as necessary to support the transfer of operation between MOE and bMOE.

The bMOE shall support all the same interfaces as the MOE, identified in sections 13.1 through 13.12. (Section 14.8 is applied for a bMOE and bMOC interface.)

Rationale: the bMOE must provide the same capabilities, with the exception that it does not contain a hardware version of the LDCM Simulator.

15 Facility Requirements

The MOE will be deployed to four facilities including the Observatory Integration & Test Facility, Instrument Development & Test Facility, Launch MOC and Launch backup MOC. This section defines the general facility and other MOE supporting baseline deployment requirements.

The MOE shall be scalable in the number of instances of each workstation and application.
Rationale: Deployments of the MOE should have the same form, fit and function in each environment. The number of copies of each workstation type or application may vary.

The MOE shall be capable of operating on U.S. standard single-phase, dual-phase and three-phase electrical power.

The MOE shall be capable of operating in a temperature range from 50 degrees F to 85 degrees F.

The MOE shall be capable of operating in a humidity range from 40% to 60%.

15.1 Observatory Integration & Test (I&T) Facility

A copy of the MOE will be deployed at the observatory integration and test facility to support MOE testing and product generation by the FOT. This site will support command and telemetry functions of the MOE.

The baseline I&T MOE shall deploy to this facility sufficient to support the following:

FUNCTIONAL UNIT	QUANTITY
Front End (Spacecraft Interface)	1
CMD/TLM Workstations	2
Trending & Analysis	1

The total aggregate space requirement for the baseline I&T MOE shall not exceed 40 square feet (contiguous). Below is a list of equipment by unit type.

UNIT	DESCRIPTION	Height (in.)	Width (in.)	Depth (in.)
Front End	Rack of equipment	TBS	24	48
CMD/TLM	Standard PC	TBS	30	30
T&A	Standard PC	TBS	30	30

The total aggregate power requirement for the baseline I&T MOE shall require a minimum of 6 20 A standard 110 Vdc circuits. Below is a list of service needs by unit type.

UNIT	DESCRIPTION	Amp	Vac	Service	Plug
Front End	Rack of equipment	TBS	110	Single Phase	R
CMD/TLM	Standard PC	TBS	110	Single Phase	R
T&A	Standard PC	TBS	110	Single Phase	R

15.2 Instrument Development & Test (D&T) Facility

A copy of the MOE will be deployed at the instrument development and test facility to support MOE testing and product generation by the FOT. This site will support command and telemetry functions of the MOE.

The baseline (TBR) D&T MOE shall deploy to this facility sufficient to support the following:

FUNCTIONAL UNIT	QUANTITY
Front End (Spacecraft Interface)	1 (TBR)
CMD/TLM Workstations	2 (TBR)
Trending & Analysis	1 (TBR)

The total aggregate space requirement for the baseline D&T MOE shall not exceed 40 square feet (contiguous). Below is a list of equipment by unit type.

UNIT	DESCRIPTION	Height (in.)	Width (in.)	Depth (in.)
Front End	Rack of equipment	TBS	24	48
CMD/TLM	Standard PC	TBS	30	30
T&A	Standard PC	TBS	30	30

The total aggregate power requirement for the baseline D&T MOE shall require a minimum of 6 20 A standard 110 Vdc circuits. Below is a list of service needs by unit type.

UNIT	DESCRIPTION	Amp	Vac	Service	Plug
Front End	Rack of equipment	TBS	110	Single Phase	R
CMD/TLM	Standard PC	TBS	110	Single Phase	R
T&A	Standard PC	TBS	110	Single Phase	R

15.3 Mission Operations Center (MOC) Facility

A copy of the MOE will be deployed at the Mission Operations Center to support pre-launch, launch.

The baseline MOC MOE shall deploy to this facility sufficient to support the following:

FUNCTIONAL UNIT	QUANTITY
Front End (Spacecraft Interface)	3
CMD/TLM Workstations	40
Trending & Analysis	3
Planning & Scheduling	2
Flight Dynamics	2

The total aggregate space requirement for the baseline MOC MOE shall not exceed 600 square feet (contiguous). Below is a list of equipment by unit type.

UNIT	DESCRIPTION	Height (in.)	Width (in.)	Depth (in.)
Front End	Rack of equipment	TBS	24	48
CMD/TLM	Standard PC	TBS	30	30
T&A	Standard PC	TBS	30	30
P&S	Standard PC	TBS	30	30

The total aggregate power requirement for the baseline MOC MOE shall require a minimum of 32 20 A standard 110 Vdc circuits. Below is a list of service needs by unit type.

UNIT	DESCRIPTION	Amp	Vac	Service	Plug
Front End	Rack of equipment	TBS	110	Single Phase	R
CMD/TLM	Standard PC	TBS	110	Single Phase	R
T&A	Standard PC	TBS	110	Single Phase	R
P&S	Standard PC	TBS	110	Single Phase	R

15.4 Backup Mission Operations Center (bMOC) Facility

A copy of the MOE will be deployed at the backup Mission Operations Center at TBS to support pre-launch, launch, commissioning and contingency activities of the LDCM observatory.

The baseline bMOC MOE shall deploy to this facility sufficient to support the following:

FUNCTIONAL UNIT	QUANTITY
Front End (Spacecraft Interface)	2
CMD/TLM Workstations	6
Trending & Analysis	1
Planning & Scheduling	1
Flight Dynamics	1

The total aggregate space requirement for the baseline bMOC MOE shall not exceed 600 square feet (contiguous). Below is a list of equipment by unit type.

UNIT	DESCRIPTION	Height (in.)	Width (in.)	Depth (in.)
Front End	Rack of equipment	TBS	24	48
CMD/TLM	Standard PC	TBS	30	30
T&A	Standard PC	TBS	30	30
P&S	Standard PC	TBS	30	30

The total aggregate power requirement for the baseline bMOC MOE shall require a minimum of 14 20 A standard 110 Vdc circuits. Below is a list of service needs by unit type.

UNIT	DESCRIPTION	Amp	Vac	Service	Plug
Front End	Rack of equipment	TBS	110	Single Phase	R
CMD/TLM	Standard PC	TBS	110	Single Phase	R
T&A	Standard PC	TBS	110	Single Phase	R
P&S	Standard PC	TBS	110	Single Phase	R

15.5 Launch Support Room (LSR)

The Launch Support Room is composed of Instrument LSR and Engineering LSR. MOE requirements for this facility are TBR.

Appendix A: Glossary

anomaly -- any unplanned or unexpected event which may result in a loss of operation data or a sharp departure of certain telemetry parameters from their nominal values – a deviation from normal operation that affects the performance of an observatory system or subsystem.

Absolute Time command Sequence (ATS) – a Command Sequence defined using command start at a specific UTC time (or spacecraft time equivalent).

Active Schedule – portion of the Master Schedule used to create the ATS command load uplinked to the observatory.

Activity – an operator-defined combination of ground directives and/or observatory commands which can be planned and scheduled. An action (or set of actions) which can occur on the ground or observatory that requires resources and is associated with a definitive start and stop time.

Activity Plan – a time-based set of activities that have yet to be scheduled

Activity Request – a request for operators to schedule activities.

Activity Schedule – a time-based or time-tagged set of activities and resource allocations for a given time period.

Command Loads – a set or packaging of commands related by execution time and/or function, converted to binary streams to be up-linked. (Packaging of both telemetry and commands can be performed in a number of ways, such as the CCSDS Telemetry and Commanding Packaging format.)

Command Sequence – a set of commands related by time. A list of stored command mnemonics identified by a unique name known to the operators that can be re-used.

Commanding -- the coding and packaging of the command information, command validation and verification, as well as authorization to perform the commands. Telemetry and Commanding are necessarily related to one another because Telemetry and Commanding form a feedback loop; the values of down-linked telemetry may play a role in deciding what command or what command parameters to send next.

Commands – Messages that instruct an action on the observatory to execute.

Command Validation – The process of ensuring that commands have the expected results when they are executed by the observatory. Includes validating the use of command parameters associated with the command mnemonics.

Command Verification – The process of verifying that command mnemonics issued within command procedures and loads, and entered manually by the operator, result in the expected bit patterns being transmitted from the control center, as defined by the

command data base. Includes verifying that the use of command parameters associated with the command mnemonics create the expected results.

Constraint Checking - The process of ensuring that constraints associated with the execution of individual commands or groups of commands are enforced, whether they are issued within command loads or procedures, or executed manually by the operator. Examples include: (1) ensuring that a particular command is not executed unless a particular on-board state is in place or a particular command had been issued before it, (2) ensuring that commands are not issued beyond some established command rate, and (3) ensuring that the number of commands allowed for a given structure, such as a command sequence, does not exceed an established limit.

Critical Command (or Critical Operations) – an observatory command which, when executed under certain conditions, could jeopardize the health and safety of the spacecraft or its subsystems. It requires the intervention/authorization of an operator before transmission.

Decommutated Telemetry – the extracted telemetry parameters from their assigned positions (such as the Major/Minor Frame Number in TDM telemetry systems or the Byte Position in a Packet within the Transfer Frame in CCSDS telemetry systems) within the telemetry stream.

Directive -- a command to the ground software system. Examples of directives are: bring up a display page, turn limit checking on/off, acquire telemetry, etc.

Engineering Unit (EU) – computed human and machine readable values for telemetry analysis Examples of Engineering Units include values for voltage, temperature (degrees K or C), kilometers, etc.

Discrete command – a single (individual) observatory command, as opposed to a spacecraft stored sequence (RTS or ATS) of commands

Event – an occurrence detectable within mission operations systems that is used to monitor and track or otherwise audit ground and space operations.

Event Message – the resulting message from a detected event

Forecast Schedule – A portion of the Master Schedule showing predicted orbital and scheduled events for the upcoming three Operational Weeks. This schedule is formally updated once per week and released for distribution.

Ground Network Element (GNE) – The LDCM GNE includes the LGN ground stations, data reconstruction subsystem, and the network/telecom (WAN).

Ground Reference Image (GRI) – the ground-based, controlled flight software version that is currently resident on the observatory representing all reprogrammable memory locations (i.e. the image/memory currently used by the On-Board Computer containing data, commands, subroutines, etc).

Ground Support Equipment (GSE) – a generic term describing hardware and software components supporting spacecraft operations on the ground. Includes FOS, DPAS and external ground interfaces.

Hazardous Command – a command which when executed may endanger the safety of human beings working on the spacecraft during I&T, launch preparation or launch. The hazardous designation is made via the command database. Hazardous commands cannot be transmitted.

Health & Safety – the discipline of monitoring observatory telemetry to check the well-being of the observatory.

Hot backup – an idle, but equivalent system or subsystem ready to take-over instantly when the primary system or subsystem fails.

Housekeeping Telemetry– observatory telemetry used in Health and Safety determination. Observatory housekeeping telemetry also includes instrument/payload telemetry.

Invalid telemetry - telemetry that is not in a recognizable format and can not be decommutated or is decommutated but contains incorrect/invalid values, etc.

Landsat Ground Network (LGN) – the specific complement of ground stations, i.e. LDCM EROS, Fairbanks Polar, and a 3rd Contingency Station.

Limit violation – an event when a telemetry parameter exceeds its expected range of values.

Log – A time-tagged list of actions or events

Master Schedule – The reference schedule for future and past schedule events for the mission. The Master schedule includes a variety of predicted orbital events, ground network schedule events, observatory real/time commands, observatory stored commands, and GSE directives.

Memory Load —generally a combination of flight software updates, table loads, and command loads that affect the on-board observatory re-programmable memory locations.

Mission Operations Element (MOE) data – all data that is received externally to the MOE, sent out from the MOE, or created for internal MOE use. Examples include: all forms of Telemetry (e.g. Raw, Calibrated, etc), all forms of Commands and mnemonics, Pass Summaries, operator-saved analysis, event messages, plans/schedules, logs, etc.

Mnemonic – an alphanumeric shorthand representation of a telemetry point or a command assigned by convention and operators, and stored in a database to reference.

Observatory – The entire LDCM spacecraft including the bus, instrument(s) and any associated components.

Pass Summary – MOE data related to an observatory pass

Periodic operations – activities performed on a routine basis that require minimal engineering support

Planning – the discipline of predetermining and coordinating the mission activities for any period of time.

Procedure – A stored sequence of commands or directives written in a high-level language with built-in flow controls (such as if-then-else, do while, case, etc.) to automate observatory operations.

Product - a report in tabular, plot, textual, or graphical form

Pseudo Telemetry – telemetry values derived by calculation often involving multiple telemetry points.

Raw Telemetry – telemetry that has not been converted into Engineering Units

Relative Time command Sequence (RTS) – a Command Sequence defined using command start times relative to the previous command start in the sequence.

Reports – operator-filtered MOE data output to a file, screen, plotter or printer

Routine operations – operations performed each contact or daily requiring no engineering support

Scheduling – the process of assigning and coordination of resources associated with planned activities, and the assignment of each planned activity to a specific time.

Scripts – a capability involving editable and stored sets of directives (see Directive) whereby mission operations ground systems administration can be accomplished automatically.

Special operations – operations requiring engineering and/or Flight Operations Team support.

Stale telemetry – the staleness test is only applied to real/time housekeeping data parameters received during the contact. If the difference between the ground receipt time of a parameter and the current GSE time exceeds a user defined threshold, the data available for display is marked as stale. In a CCSDS packet structure, each packet would be assigned a staleness threshold, generally equal to twice the packet period and processing overhead.

State transition – an event when the observatory, one of its subsystems or telemetry parameters enters or exits an operator-defined, detectable condition

Stored Command – a command awaiting execution onboard the observatory.

Stored Command Load – an assembled set of commands related by relative or absolute execution time used to perform a specific function. The command set has been converted to binary streams to be up-linked to form the stored command load.

Table Load -- An uplink of observatory parameters that typically reside in specific on-board memory locations

Telemetry – Includes housekeeping telemetry and pseudo telemetry.

Telemetry Counts – discrete values for raw specific telemetry points

Telemetry parameters – values used in the determination of observatory health and safety.

Trending – the discipline of tracking telemetry values for any number of recent or historical telemetry downlinks.